Book of Abstracts & Posters

Measuring, Modeling and Managing of the natural processes related to water flows - Social values of the linked ecosystem services

United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

European Regional Centre for Ecohydrology Under the auspices of UNESCO

ERASMUS MUNDUS MASTER OF SCIENCE IN ECOHYDROLOGY

EcoHydrology 2015

Lyon, France, from 21 to 23 September

http://ecohydrologie.sciencesconf.org/

INTRODUCTION

This compendium of abstracts gathers the oral and posters presentations that have been given during the conference EcoHydrology ' 2015.

It is organized into four main topics:

(I) Approaches to modeling and management of eco-hydrological processes
(II) Methods and models for the determination of environmental flows in rivers and estuaries
(III) Social and economic values of water-related ecosystem services
(IV) Environmental monitoring and measuring of water-related natural processes

The Unesco demosites network in EcoHydrology was also presented. It serves as a platform where to implement in a coherent way the topics of this conference. It is already the case, as illustrated during the conference, for the applied research developed by the master students of the Erasmus Mundus network in EcoHydrology.

Ecohydrology'2015 is the second conference of a biennial cycle that is expected to run until 2021 in the frame of the International Hydrological Programme of the UNESCO.

The Steering committee was composed by:

G. Arduino (UNESCO), Prof. M. Zalewski (ERCE), Prof. MC Clain (IHE), Prof. L. Chichario (Univ. Algarve) and Dr.P. Breil

The core scientific committee was composed by:
Dr. G. Arduino (UNESCO), Dr. P. Breil (IRSTEA), Dr. M. Cottet (ENS) Dr. Ph. Namour (ISA) and Prof. P. Parasiewicz (IRS).

Dr. P. BREIL, who chairs this second conference, has edited this compendium.

Table of Content

List of first authors by names

S

T

U

W

Y

Z

Topic 1 : Approaches to modeling and management of eco-hydrological processes

COUPLING HYDROLOGY AND MICROBIAL COMMUNITY DYNAMICS IN URBANIZED AREAS: INSIGHTS FROM THE RIVER TEVERE (ROME, ITALY)

Stefano Amalfitano[a], Stefano Casadei[b], Stefano Fazi[a]

[a] Water Research Institute, National Research Council of Italy (IRSA - CNR), Via Salaria, km 29.300, Monterotondo, Rome, 00015, Italy.

[b] Department of Civil and Environmental Engineering, University of Perugia, Borgo XX Giugno 74, Perugia, 06121, Italy.

Key words
River ecohydrology, hydrological index, microbial ecology, flow cytometry

Topic 1: Approaches to modeling and management of eco-hydrological processes

Topic of this work

River waters at lowland reaches experience a direct disturbance owing to increasing water resource exploitation and urbanization, with important implications for ecosystem functioning and services. Despite decreasing water quality and altered hydrological regime may dramatically affect the natural processes as a whole, little is known on the effects on aquatic microbial communities, whose dynamics play a key role in organic matter decomposition and nutrient cycling along the river continuum.

Research question (or operational application)

The objective of this study was to explore the links between hydrology and microbial community structure in a highly impacted Mediterranean river.

Originality of this work

The link between water quality and ecosystem is investigated with attention to water uses in the basin. The hydrologic characteristics and the water withdrawals are analyzed by means of indicators. This approach is characterized by high performance but it can be possible only with a deep knowledge of the total basin or sub-basin, in term of hydrologic and water withdrawal data.

Data and / or method

To this aim, the catchment of the River Tevere (Rome, Italy) was sampled in differently urbanized areas at two contrasting seasons (winter/summer). Water was sampled from the River Tevere, upstream and downstream the city of Rome, fromthe main tributary (the River Aniene),from a lower order stream (Cremera, Stream) and a pristine spring.The major hydrological, physical and chemical characteristics of river waters were measured directly, or retrieved within datasets from monitoring agencies.Synthetic hydrological indices were elaborated in the selected river sections. In particular,the $Q_{7,10}$index was used to describe the low flow characteristics of the river represented by the time series of annual minimum flow averaged

over an interval of 7 consecutive days with a return time of 10 years. The flow duration curve and Q_{355} index (i.e., a low-flow index indicating the streamflow that is equaled or exceeded 355 days in a year, on average),were used to synthesize the hydrological status of each section of the river network, with particular attention to anthropic impacts.The results were discussesbased on the water use and consumption and were related to the basin characteristics. The microbial community structure was analyzed by flow cytometry for the rapid cell quantification of aquatic prokaryotes and picoeukaryotes (i.e., heterotrophs and photoautotrophs).

Main results

Our results outlined recurrent patterns and quantitative changes of interacting microbial assemblages across the urbanization gradient at different hydrological settings. The total prokaryotic cell abundance increased toward the river mouth, with higher values registered downstream the city of Rome (4*10^6 cells/ml). The per-cell nucleic acid content, intended as a proxy of the cell metabolic activity, increased accordingly, while the ratio between photoautotrops and heterotrophs decreased downstream the confluence with main tributary (the River Aniene).

Conclusion & Perspectives

Given the links between hydrological and microbial community patterns, river microbes could provide valuable indications on the ecological effects of urbanization and altered environmental conditions. Moreover, flow cytometry seems an appropriate tool to rapidly provide multi-parametric data for a better understanding of the biogeochemical processes at the microscale level in river systems.

STORMWATER INFILTRATION IN A PERI-URBAN CATCHMENT: WHERE DOES THE WATER GO?

Bonneau J. *, Fletcher T.*, Burns M.*

**Faculty of Science, The University of Melbourne, 500 Yarra Boulevard, Burnley, VIC, 3121*

Key words

Baseflow, drainage, urban karst, stormwater management, stream

Topic of the work

1.4 Urban Ecohydrology – storm water purification and retention in the city landscape, potential for improvement of health and quality of life

Research question

In urban catchments, the prevalence of impervious surfaces reduces water infiltration. This often leads to reductions in stream baseflow (Price, 2011). The practice of stormwater infiltration has been widely promoted to restore depleted baseflow in urban catchments (Walsh et al., 2005). However, the hydrological implications of stormwater infiltration—at the catchment-scale—are largely unknown (Cizek & Hunt, 2013; Hamel et al., 2013). We do not understand for example, how much infiltration stormwater reaches the stream, the timing of this flux, etc. Answering such questions is complicated by the presence of underground infrastructure (e.g. pipes, sewers, telecommunications, etc.)—often described as the urban karst (Kaushal & Belt, 2012)—which create preferential pathflows for groundwater and subsurface flows. Gravel, sandy beddings, trenches or other high permeability construction material are likely to drain urban groundwater much quicker in an urban catchment than in the pre-development condition (Sharp et al., 2013). The 'urban karst' therefore has the potential to limit the baseflow restoration capacity of infiltration systems. Thus understanding the fate of infiltrated stormwater warrants consideration of the urban karst.

Originality of the work

While many studies have quantified the site-scale performance of stormwater infiltration systems (Davis, 2008; Hunt et al., 2006; Li & Sharkey, 2009), few researchers have examined the impact of these systems at larger scales. Our aim here is to track the fate of infiltrated stormwater from a large-scale infiltration system. We aim to use an extensive network of piezometers to track infiltrated stormwater from site to receiving water.

Methods

We monitored the hydrological performance of a large-scale combined bio-filtration and infiltration system (~2000 m^2) for 15-months. The system has an elevated underdrain, allowing filtered water to be discharged to the receiving stream, but with an unlined base, there is also a potentially large infiltration flux. We also monitored the level of shallow groundwater both around the system and longitudinally from the site to the receiving stream, some 300m downslope of the infiltration basin.

We firstly quantified the water balance of the system in order to calculate site-scale stormwater infiltration. We then used the water level data immediately downstream of the system and the Penman Monteith equation to estimate evapotranspiration. And finally, we used water level data from all the bores to track the plume of infiltrated stormwater.

Results

Over the study period (Jan-2014 to Mar-2015), most catchment inflows entered the system (86%, 41,000 kL) with little bypass (overflow). The majority of water entering the system was treated by the filter and released via the underdrain at low-flow rates back into the stormwater drainage network

(~28,800kL, 61% of the impervious volume). Around 10% (~5,000kL) of the system inflows were evapotranspired by the plants at the surface of the filter and by the vegetation downslope of the basin.

Around 7,100 kL (15% of the impervious runoff volume) of the system inlet was infiltrated into the surrounding ground, contributing to raise the local groundwater table and flow downslope. References bores were dry during the observed period, meaning that the natural groundwater table does not interact with the filter, and that shallow water observed 20m downslope of the basin is thus likely to be infiltrated stormwater. However we did not observe any changes to the groundwater level 75m downslope, next to the protected stream, being impacted by the infiltration system, which indicates that the interaction between stormwater infiltration and the stream is unclear. The behaviour of the system has strong seasonal variations. Importantly, strong interaction between the plume of infiltrated stormwater and a sewer trench was observed during dry months (summer).

Discussion

These findings suggest that the potential for stormwater infiltration to increase catchment-scale low-flows can be limited by the presence of underground infrastructure. These observations are evidence that infiltration basins can have a local impact, but that catchment scale consequences for baseflow processes are limited by the urban karst. Theoretically, it may be impossible to restore natural baseflow pathways in an urban catchment, or more optimistically, there may be a ‘ceiling of maximum achievable restoration’ in urban catchments. Conceptually, even if one would infiltrate 100% of impervious runoff, low flow hydrology (i.e., transit time, storage pattern, natural pathways) would still be greatly disturbed by the urban karst. From a management point of view, results indicate that care must therefore be taken when selecting locations for stormwater infiltration. In particular, recharge areas and maps of underground infrastructure could be taken into account.

Acknowledgements

This project is funded by Melbourne Water and Knox City Council.

References

Cizek, A. R., & Hunt, W. F. (2013). Defining predevelopment hydrology to mimic predevelopment water quality in stormwater control measures (SCMs). *Ecological Engineering, 57*, 40-45. doi: 10.1016/j.ecoleng.2013.04.016

Davis, A. P. (2008). Field performance of bioretention: Hydrology impacts. *Journal of Hydrologic Engineering, 13*(2). doi: 10.1061//asce/1084-0699/2008/13:2/90

Hamel, P., Daly, E., & Fletcher, T. D. (2013). Source-control stormwater management for mitigating the impacts of urbanisation on baseflow: A review. *Journal of Hydrology, 485*, 201-211. doi: 10.1016/j.jhydrol.2013.01.001

Hunt, W. F., Jarrett, A. R., Smith, J. T., & Sharkey, L. J. (2006). Evaluating bioretention hydrology and nutrient removal at three field sites in North Carolina. *Journal of Irrigation and Drainage Engineering*. doi: 10.1061//asce/0733-9437/2006/132:6/600

Kaushal, S. S., & Belt, K. T. (2012). The urban watershed continuum: evolving spatial and temporal dimensions. *Urban Ecosystems, 15*(2), 409-435. doi: 10.1007/s11252-012-0226-7

Li, H., & Sharkey, L. (2009). Mitigation of Impervious Surface Hydrology Using Bioretention in North Carolina and Maryland. *Journal of Hydrologic Engineering*. doi: 10.1061//asce/1084-0699/2009/14:4/407

Price, K. (2011). Effects of watershed topography, soils, land use, and climate on baseflow hydrology in humid regions: A review. *Progress in Physical Geography, 35*(4), 465-492. doi: 10.1177/0309133311402714

Sharp, J. M., Krothe, J. N., Mather, J. D., Gracia-Fresca, B., & Stewart, C. A. (2013). Effects of Urbanization on Groundwater Systems. 257-278. doi: 10.1029/SP056p0257

Walsh, C., Fletcher, T. D., & Ladson, A. R. (2005). Stream Restoration in Urban Catchments through Redesigning Stormwater Systems: Looking to the Catchment to Save the Stream. *Journal of the North American Benthological Society, 24*(3), 690-705.

CAN WE COMBINE THE PLUVIAL FLOODING CONTROL AND THE ECOSYSTEM SERVICES PRESERVATION IN SMALL STREAMS EXPOSED TO A RAPID URBAN DEVELOPMENT?

Pascal Breil, Irstea, Hydrology-HydraulicResearch Unit, 5 rue de la Doua, 69626, Villeurbanne (France)

OldrichNavratil, University of Lyon, Laboratory Environment, City & Society, 5 av. P. Mendès France, 69676 Bron (France)

Laurent Schmitt, University of Strasbourg, Laboratory Image, City & Environment, 3 rue de l'Argonne, 67083 Strasbourg (France)

BiljanaRadojevic, UNESCO, Natural Science Sector, 1 Rue Miollis, Paris (France)

Key words :urban expansion, urban flood, on-site rainwater retention, bankfull flow, streambed incision

(topic 1)

Topic of this work

This article presents a risk management strategy for flood that would be implemented in areas that are prone to rapid urban expansion. We develop this study on a periurban watershed of 150 km2 which is located in the vicinity of the city of Lyon (France) and where major investments by national, regional and local authorities have been spent since 2008 to reduce the urban pollution sources and the danger of extreme hydrological events such as floods and drought. These actions help restore lost ecosystem services such as the processing of organic substances that improves the quality of surface water, human health and provide economic benefits to society.

Research question (or operational application)

To avoid that the rapid periurban development reduces the effect of the restoration action we develop a modeling approach to test if the systematic implementation of on-site rainwater retention devices for new constructions between 2008 to 2030 can counterbalance the urban storm water runoff increase which is the source of detrimental effects for small streams. A major constraint remains to maintain the occasional overflows from sewer systems to ensure the protection of downstream dense urban areas against pluvial flooding. Then a main question is how far the on-site rain water retention can protect the receiving streams from geomorphic damages like the incision?

Originality of this work

Most of the studies focus on the origin of the geomorphic incision process but do not consider its role on the water ecosystem functioning.In this study the incision process is taken as a proxy indicator of a detrimental effect for the carrying capacity of the hyporheic zone.

Data and / or method

We use in a first step an existing data set (Navratil& al, 2013) of geomorphic characteristic describing 17 stream courses natural and incised of the studied basin. This set is used in combination with a probabilistic model of the flood regime of the studied basin (Breil&Radojevis,). This allows calibrate two prediction models of the bankfull flow value in relation to the 2-year return period flow value, one for the natural and the other for the incised river stretches. In a second step we use the simulated scenario of the urban development in 2030 ( ) for 45 sub-basins of the study basin area.

Main results

The results show the importance of considering the absorption capacity of a stream, here translated as a greater or lesser sensitivity of the river bed incision process. The principle of EcoHydrology is based on the dual regulation of biotic properties and of flows in rivers.

Conclusion

We can conclude from these data that the use of alternative storm-water practices can limit the impact of their overflows on small streams. However, it is necessary to identify the water course segments that can better resist to the incision process. This resistance can be natural or boosted using eco-technologies. This last possibility is presented in another paper.

Aknowledgements

Much of the presented research was (is) supported by the French National Research Agency (ANR-07-VULN-01; ANR-O8-CESA-022; ANR-10-ECOT-007-01), the Rhône-Alpes Region, the Rhône–Mediterranée-Corse Water Agency, the Lyon city Council, the River Basin Contract (SAGYRC at http://www.riviere-yzeron.fr/) and the Field Observatory for Urban Water Management (OTHU at http://www.graie.org/othu/).

Cited references

Breil P., Radojevic B., Chocat B., 2010: “Urban development and extreme flow regime changes” In Global Change: Facing Risks and Threats to Water Resources (Proc. of the Sixth World FRIEND Conference, Fez, Morocco, October 2010). IAHS Publ. 340

Jacqueminet C., Kermadi S., Michel K., Béal D., Gagnage M., Branger F., Jankowfsky S., BraudI.. 2013: Land covermappingusingaerialand VHR satelliteimagesfordistributedhydrologicalmodellingofperiurbancatchments: ApplicationtotheYzeroncatchment (Lyon, France). Journal ofHydrology, Vol. 485: 68-83. doi:10.1016/j.jhydrol.2012.01.036.

Navratil O., Breil P., Schmitt L., Grosprêtre L., Albert M.B., 2013: Hydrogeomorphicadjustments of stream channels disturbed by urban runoff (yzeron river basin, France). *Journal of Hydrology*, Vol. 485: 24-36. doi:10.1016/j.jhydrol.2012.01.036

PREDICTING STREAMFLOW REGIME FOR ECOLOGICAL STUDIES IN TEMPORARY RIVERS

Anna Maria De Girolamo, Istituto di Ricerca Sulle Acque-Consiglio Nazionale delle Ricerche (IRSA-CNR), Bari, annamaria.degirolamo@ba.irsa.cnr.it

Giuseppe Pappagallo, Istituto di Ricerca Sulle Acque, Consiglio Nazionale delle Ricerche (IRSA-CNR), Bari

Antonio Lo Porto, Istituto di Ricerca Sulle Acque, Consiglio Nazionale delle Ricerche (IRSA-CNR), Bari

Key words:

(2.5, 2.7) Temporary river, Flow regime, Hydrological Model, Hydrological Indices

Topic of this work

Hydrological regime is a key factor in riverine processes, influencing not only sediment and nutrient delivery, but also composition, structure and function of aquatic ecosystem. Thus, a characterization of hydrological regime in a river section has a great importance in defining the hydrological and ecological status of a river. Flow regime characterization needs measured streamflow data, which are often unavailable, especially in Mediterranean Basin. When streamflow measures are not available, hydrological models can constitute useful and powerful tools that allow to simulate flow discharge both in natural and impacted conditions. In addition, models can give a contribution in answering crucial questions such as Environmental Flows, in quantifying hydrological alterations due to human activities and climate change.

Research question

Although in recent decades several models have been developed, their use in rivers with a temporary character is quite complex. In addition, there is a limited information in literature able to facilitate model applications and to validate results in the Mediterranean region. The high spatial variability which characterizes rainfall events, soil hydrological properties and land uses of Mediterranean basin makes more difficult to simulate hydrology and water quality in this region than in other Countries.

Through a case study: the Celone river (S-E Italy), a temporary river where a dam has generated alterations in the downstream flow regime, the authors analyze several aspects involved in modeling hydrological processes including model data requirements, data availability, model results and uncertainty. The general replicability of some hydrological indicators evaluated by using simulated streamflow data, that are generally proposed for ecological flow needs and anthropogenic impacts assessments, was tested.

Originality of this work

This study is not intended to be an evaluation of the capabilities of the SWAT model and the processes it represents, or of the basin characteristics. Going beyond a typical streamflow simulation of a

temporary stream, we focused on the general capabilities and uncertainties surrounding the replications of hydrological indicators. We try to analyze and discuss what ecologists can expect from hydrological models and the problems which hydrologists have to face in modelling streamflow in Mediterranean rivers.

Data and method

We applied the proposed methodology to the River Celone located in the Apulia region in southern Italy. The channel, which is incised in the upper basin, assumes a braided form in an alluvial plain downstream of the steeper reaches. The drainage area is 317 km^2 and the main river course is 93 km long. The river flows northeast and enters the Capaccio reservoir. The river network shows an intermittent character, with a pattern of zero or low flow and the reduction of the surface water into isolated pools along the river during the summer months. From June to September flash flood events are quite common. We used the SWAT model, version SWAT2005 with ArcGIS interface, to simulate streamflow values in two river sections on the River Celone. In the first SWAT simulation, the anthropogenic impacts were included and after the calibration and validation a new simulation without hydrological pressures was undertaken in order to predict the natural streamflow. The "Indicators of Hydrological Alteration (IHA)" which uses 32 indices to describe hydrological regime and its deviation from un-impacted condition were applied.

Main results

The model was calibrated and validated. The performance of the model simulation, evaluated by using Nash and Sutcliffe efficiency (NSE) and the correlation coefficient (R2), is satisfactory. However, the simulation of low flow is a weak point in the predictability of the SWAT model. Generally, a discrepancy between measured and simulated flow is recorded in extreme low-flow conditions, which tend to be overestimated by SWAT model.

The replicability of the IHAs ranges from good to limited. The results showed good performance for the annual flow, monthly and peak flows and limited performance for low flow, number of zero flow days, A number of factors that cause such discrepancies were identified, such as errors in meteorological inputs, and errors in observed and/or simulated discharge data. Additionally, model structure, spatial variability of data, uncertainties which affect the model's ability to replicate observed flows (especially low flow) and contribute to the discrepancies.

Conclusions

The success, or lack in capturing the statistical characteristics of IHAs using the SWAT model raises important questions regarding the applicability of hydrologic models for simulated indicators used for environmental flow assessments, especially in temporary rivers. The SWAT model performs better for the indicators for which it is calibrated (high flow). While, it shows a discrepancy for indicators such as low flows, which is likely due to systematic bias. This suggests the possibility of improving the model performance by using a "zero flow" thresholds that can potentially lead to improved performance for low-flow components of streamflow. The results of the present study can be of interest for ecologists, hydrologists and water resources managers.

THE DYNAMICS OF WOOD VEGETATION COVERAGE AND DEEP SOIL MOISTURE IN DRYLAND ECOSYSTEMS

Dinghai Zhang

Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences
haibingv@hotmail.com

Key words (5 at the most)

Topic number (1)

Dryland ecosystem, Rainfall intermittency, Rain intensity, Wood vegetation coverage, Deep soil moisture

Topic of this work

The domain: Dryland ecohydrology ---The relationship between vegetation and soil moisture in dryland ecosystem.

Research question (or operational application)

Our research focus on how the intensity and intermittency of precipitation affect woody vegetation coverage and soil moisture in dryland ecosystem.

Originality of this work

Vegetation in dryland ecosystems are usually amazingly characterized by the coexistence of two plant life forms-woody vegetation (include wood vegetation and trees) and herbaceous vegetation. Such widespread of coexistence has attracted several ecologists over the past 40 years. Broadly, the interpretation theory proposed to explain such phenomenon divided into two categories-the classic niche-separation mechanisms and the demographic-bottleneck models. However, how the precipitation affect the vegetation coverage and soil moisture based on the fact of coexistence has not been research. In my research, we give a simple Ecohydrological model to explain how the intermittency and intensity of the precipitation affect the wood vegetation and deep soil moisture. We first divided the soil moisture into two layer (the surface soil layer and the deep soil layer) according to the niche-separation theory. We assumed that the deep soil moisture play a crucial role in wood vegetation growth. The dynamic of wood vegetation has been described by using population growth theory and the dynamics of deep soil moisture described by using the probabilistic soil moisture dynamics model according to Rodriguez-Iturbe's model.

Data and / or method

To demonstrate the correctness and feasibility of the model, we collect the actual data of wood vegetation coverage and deep soil moisture from the large deserts and large sandlots in China (included The Maowusu Sandy Grassland (Yan Chi), Tengger Desert (Shapotou), Horqin Sandy Land (Naiman Banner), The Fringe of Desert Oasis, Horqin Sandy Land (Zhanggutai) and Gurbantunggut Desert). In order to further verify the effectiveness of the model in other dryland ecosystems, the woody vegetation coverage data from African savannas (Sankaran *et al.* 2005) have been used.

In my research, we use a model coupling the wood vegetation coverage and deep soil moisture and the Monte Carlo method has been used to simulate the model.

Main results

The model revealed that both the wood vegetation coverage and deep soil moisture increased with the increase of precipitation intensity, but the former is faster than the later in arid and semi-arid regions. The precipitation intermittency is an important variable to promote the wood vegetation coverage growth in dryland ecosystems. When the annual rainfall amounts is fixed the bigger precipitation intermittency the larger wood vegetation coverage and deep soil moisture. These results well agree with the experimental observations from African savannas and deserts of China.

Conclusion & Perspectives

We first propose a conceptual framework of “eco-hydrological threshold” and give a reasonable range of wood vegetation coverage and deep soil moisture in different types of arid and semi-arid regions. It is very important for further investigate practical ecological restoration and sand hazard mitigation in desert.

Aknowledgements

This research was supported by the National Basic Research Program of China (973 Program No. 2013CB429900)，West Light Program for Talent Cultivation of Chinese Academy of Sciences, and National Natural Science Foundation of China (No. 31360104).

MULTICRITERIA DECISION-MAKING UNDER UNCERTAINTY: A GRAPHICAL APPROACH FOR COMPARING THE SUSTAINABILITY OF URBAN FLOOD RISKSMANAGEMENTSTRATEGIES

Abla M. Edjossan-Sossou , GeoRessources (Université de Lorraine) - INERIS, abla-mimi.edjossan-sossou@univ-lorraine.fr

Olivier Deck, GeoRessources (Université de Lorraine), olivier.deck@univ-lorraine.fr
Thierry Verdel,GeoRessources (Université de Lorraine), thierry.verdel@univ-lorraine.fr Marwan Al Heib,INERIS, marwan.alheib@ineris.fr

Key words (5 at the most)

(1.1 – 3.1)/ Sustainability assessment – Multicriteria decision-making –Uncertainty – Radar graphs

Topic of this work

This study pertains to decision-makingin the urban flood risks management field.It concentrates on the sustainability assessment of management alternatives in an uncertain context.

Research question (or operational application)

The main research question that this study focuses on is as follows: how decision-makers could address uncertainty when assessing the sustainability of management alternatives? As a predictive decision-making, urban flood risks management involves uncertainties arising from a lot of sources. Nowadays practical concerns of uncertainty are amongst the topics in which increasing interest is being focused on, and one of the crucial issues is how to present uncertainty related to multicriteria analysis results.This study aims to provide an introduction to this issue in the urban flood risks management field, and to suggest a tool that enables decision-makers to visualize the range of expected sustainability performance of their decisions in order to deal with uncertainty in the easier.

Originality of this work

The originality of this study is twofold. First, it elaborates a framework for a comprehensive assessment of urban flood risks management decisions from a sustainability perspective, which creates an opportunity fortackling those risks sustainably.Indeed, most of cities around the world are facing flood risks that can lead to significant damages. In extreme cases, those risks can result in disasters that may set back cities development by years or even decades. Although considerable efforts have been made to manage those risks, surprisingly, their damages are constantly increasing. A lot of reasons undermine the effectivity of cities in managing flood risks, amongst which the current approach adopted in management decision-making. This approach, based only on economical and engineering concerns regardless to environmental and social aspect, is not suitable to tackle sustainably urban flood risks. Accordingly sustainable management of flood risks is becoming an increasingly challenging task for cities. Second, to facilitate decision-makingthe complex interplay between the economic, environmental and social aspects of sustainability needs to be understood. In addition, by its nature, *ex*

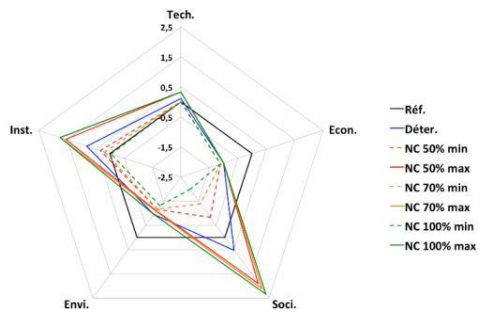
ante sustainability assessment entails uncertainty. It is necessary for the operational application of sustainability assessment to estimate the reliability of its predictions. That means to take into account and to quantify uncertainty. Thus, information visualisation, through an overall picture that allows a broad understanding, can play an important role for exploring sustainability assessment results variability understood. To facilitate graphical analysis of the results of a sustainability assessment under uncertainty, this study aims to suggesta graphical approach involving radar graphas a tool that enables decision-makers to visualize the range of expected sustainability performance of their decisions.

Data and method

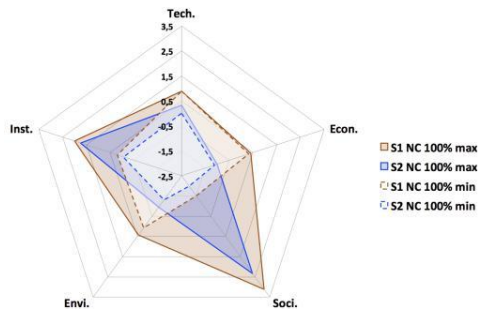
An application is provided to illustrate the approach. The study is a municipality located along the Moselleriver that faces typically slow floods due to the river overloaded discharges into the city.The sustainability of a set of alternatives was assessed applying a method elaborated for the necessity of the INCERDD research project. This method is based on acriteria-grid (a set of generic indicators and criteria; quantitative indicators are split on specific parameters for each particular case and context), and combines sustainability assessment protocol with an uncertainty (quantification for all inputs and propagation for parameters to criteria) estimation protocol. A combination of three techniques was used to estimate uncertainty related to the performance of criteria: Monte Carlo Analysis for quantitative indicators, Possibility Theory for qualitative indicators and Interval Theory for criteria. Current data were collected from literature, interviews of stakeholder, and databases. Then they wereprojected in 5, 10 and 30 years assuming pessimistic, deterministic (expected), and optimistic scenarios.

Main results

By observing figures below, the main results are as follows. Radar graphs depict the contribution of the five sustainability criteria to the global sustainability performance. Thresholds related to each certainty level can be determined. Thus it becomes easy to check if the deterministic result belongs to the obtained confidence interval. In figure (a) thevalue of environmental sustainability criterion (herein "Envi.") doesn't belong to the confidence intervals at 50% and 70% degrees of certainty. Drawing together results of competing alternatives, as shown in figure (b)for strategies S1 and S2, allows a quick scan assessment of the attainment of sustainability objectives. These results demonstrate that visual analysis can be useful for decision-making relied on two or more criteria and radar graphs canbe relevant tool to do so.



(a)



(b)

The interest of the proposed approach is the ability to help visually identifying: strengths and weaknesses of each management alternative, a certainty level of the predicted performance for each sustainability criterion, in which context an alternative or strategy could be the most sustainable on the basis of the robustness of alternatives rankings according to the retained certainty level, etc. This

approach can practically be applied by decision-makers in deciding, under uncertainty, on any multicriteria problem such as sustainability assessment.

Aknowledgements: This study were conducted within the scope of the INCERDD research project (prise en compte des INCERtitudes pour des Décisions Durables) supported by AgenceNationale de la Recherche (ANR). Special thanks to all partners of this project

CAN CATCHMENT-WIDE STORMWATER RETENTION REALLY RESTORE AN URBAN STREAM? EARLY SIGNS FROM THE LITTLE STRINGYBARK CREEK PROJECT

Tim D. Fletcher, School of Ecosystem & Forest Sciences (Waterway Ecosystem Research Group), University of Melbourne (tim.fletcher@unimelb.edu.au) (all authors have the same affiliation) Christopher J. Walsh (cwalsh@unimelb.edu.au)

Darren G. Bos (dbos@unimelb.edu.au)

Matthew J. Burns (matthew.burns@unimelb.edu.au)
Samantha J Imberger (samantha.imberger@unimelb.edu.au)

Key words (5 at the most)

Urban ecohydrology, Ecohydrology system solution, Hydrological dimension of catchment

Topic of this work

Hydrological, water quality and ecological monitoring of the restoration of an urban stream through catchment-scale stormwater retrofit.

Research question (or operational application)

The „urban stream syndrome" (Walsh et al., 2005b) describes the seemingly inevitable degradation of the hydrology, water quality, geomorphology and consequently ecology that results from urbanization. Such degradation has been shown to be related to the proportion of a catchment made up of impervious surfaces which drain directly to receiving waters via a constructed drainage system (Hatt et al., 2004; Vietz et al., 2014; Walsh et al., 2012; Walsh et al., 2005a). A fundamental scientific question is therefore "Could the hydrology, water quality and ultimately ecology of a degraded urban stream be restored by the application of stormwater treatment, harvesting, retention and infiltration throughout its catchment?".

Originality of this work

The Little Stringybark Creek (LSC) Project (see www.urbanstreams.unimelb.edu.au) is perhaps the first project in the world to test whether catchment-wide application of stormwater control measures (stormwater harvesting, infiltration, raingardens, etc) can improve the (i) hydrology, (ii) water quality and (iii) ecological condition of a degraded urban stream. One other study, the Shepherd Creek Project, had similar objectives, but was not able to implement works at a sufficient scale where a measurable response in the receiving water was likely(Roy et al., 2014). The LSC experiment is based on a Before-After-Control-Reference-Intervention (BACRI) experimental design, where changes in the LSC catchment are compared to changes over time in the control catchments (similarly urbanized, but without interventions) and reference (forested) catchments(Roy, et al., 2014).

Data and / or method

The Little Stringybark Creek catchment is a 4.5 km^2peri-urban catchment, with a total imperviousness of 13% (connected impervious = 7.3%). The catchment is made up of some 1000 households, 750 of which are directly connected to receiving waters via the stormwater network. Monitoring in LSC and the three control and three reference catchments commenced in 2001. Since 2008, a total of 300 interventions has been constructed, including 238 undertaken on individual allotments (ie. household scale), 45 within the streetscape and 11 large projects dealing with stormwater from public, commercial or industrial land. The intervention works are scheduled for completion in early 2016(Walsh et al., 2015). All intervention works are designed based on four objectives:

1. To reduce the frequency of stormwater runoff from a site to the frequency of surface runoff occurring in the pre-developed state;
2. To restore the pre-development volume and temporal pattern of contributions to baseflow;
3. To improve water qualityto meet local receiving water standards (ANZECC & ARMCANZ, 2000);
4. To reduce the overall volume of water discharged from a site to near the pre-development level.

The rationale for these objectives is that delivering a flow and water quality regime that is near natural provides the best opportunity to maintain a healthy receiving water (Poff et al., 1997).

Streamflow was monitored in the mainstem of the creek as well as in its three tributaries and the reference and control streams. Water quality samples are taken on a monthly basis, as well for storm events, and analysed for TSS, TP and TN, along with EC and DO (in-situ measurements). Analysis for heavy metals and nutrient species is undertaken for a subset of events. Ecological monitoring includes macroinvertebrates, diatoms, benthic algae and fish. Leaf breakdown rates are also measured.

Main results

Prior to the commencement of the intervention works, the LSC catchment contained around 31 ha of connected impervious areas. To date, the intervention works have "treated" 14.5 ha(Walsh, et al., 2015), leaving some 16.5 ha still untreated, although a further 4 ha will be treated by early 2016. Monitoring to date has shown:

1. Small but distinct impacts on hydrology. The runoff coefficient for individual stormwater events has reduced subsequent to the implementation of the catchment retrofit works, in a way that is not seen in the control catchments. The results suggest that we have succeeded to a small degree in increasing the catchment average „initial loss", but the untreated areas of course remain a problem.
2. Clear decreasing trends in the concentrations of TSS, TN and TP. For example, concentrations of TP are now typical of those observed in the forested reference streams in the region.
3. No clear trend in Electrical Conductivity (EC), possibly due to increased groundwater flows.
4. No ecological responses as yet, perhaps reflecting a lag or simply that further intervention is required to achieve an ecological response.

Discussion

It is too early to definitively answer the primary question of whether retrofitting the catchment can restore the condition of urban streams, but early signs are positive. There are important questions about whether the change to channel form and habitat availability will limit the restoration trajectory.

The project has implications not only for management of existing urban streams, but for protection of streams in catchments that are yet to be urbanized.

Acknowledgements

This project has been supported by Melbourne Water, along with Commonwealth Government, Victorian State Government, Yarra Ranges Council, Yarra Valley Water, Monash University, CRC for Water Sensitive Cities, Storm Consulting and the Australian Research Council (projects FT100100144, LP0883610 and LP130100295).

References

ANZECC, & ARMCANZ. (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Canberra: Australian and New Zealand Environment and Conservation Council.

Hatt, B. E., Fletcher, T. D., Walsh, C. J., & Taylor, S. L. (2004). The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams. *Environmental Management*, *34*(1), 112-124.

Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., . . . Stromberg, J. C. (1997). The natural flow regime. *Bioscience*, *47*, 769–784.

Roy, A. H., Rhea, L. K., Mayer, A. L., Shuster, W. D., Beaulieu, J. J., Hopton, M. E., . . . Amand, A. S. (2014). How Much Is Enough? Minimal Responses of Water Quality and Stream Biota to Partial Retrofit Stormwater Management in a Suburban Neighborhood. *PloS one*, *9*(1), e85011.

Vietz, G., Sammonds, M., Fletcher, T. D., Walsh, C. J., Rutherfurd, I., & Stewards, M. (2014). Ecologically relevant geomorphic attributes of streams are impaired by even low levels of watershed effective imperviousness. *Geomorphology*, *206*, 67-78. doi: http://dx.doi.org/10.1016/j.geomorph.2013.09.019

Walsh, C. J., Fletcher, T. D., Bos, D. G., & Imberger, S. (2015). Restoring a stream through retention of urban stormwater runoff: a catchment-scale experiment in a social–ecological system. *Freshwater Science*, *34*(3). doi: 10.1086/682422

Walsh, C. J., Fletcher, T. D., & Burns, M. J. (2012). Urban stormwater runoff: A new class of environmental flow problem. *PLOS ONE*, *7*(9), e45814.

Walsh, C. J., Fletcher, T. D., & Ladson, A. R. (2005a). Stream restoration in urban catchments through redesigning stormwater systems: looking to the catchment to save the stream. *Journal of the North American Benthological Society*, *24*(3), 690-705.

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Morgan, R. P. (2005b). The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, *24*(3), 706-723.

USING GIS-BASED MODELLING TO DEVELOP LOCAL AND NATIONAL IRISH RAISED BOG CONSERVATION PROGRAMMES.

Topic: Ecohydrology system solution and ecological engineering for the enhancement of water and ecosystem resilience and ecosystem services

Raymond Flynn , The Queen's University of Belfast. r.flynn@qub.ac.uk

Francis Mackin, RPS Ireland, Belfast.francis.mackin@rpsgroup.com

Alan Barr, RPS Ireland, Belfast.alan.barr@rpsgroup.com

Key words: *Raised Bog, Habitats Directive, Restoration.*

Raised bog has become an extremely rare habitat across the EU. In Ireland, human activity has resulted in the loss of over 80% of the 311,000 hectares of uncut Atlantic raised bog that once covered the country, most of which has been lost in the last 50 years. Since the late 1980s a growing realization of the increasing rarity of this habitat has prompted a number ofecohydrological investigations to assessthe impacts of processes such as peat cutting and drainage on raised bog ecological health with a view to developing effective conservation programmes. Promulgation of the EU Habitats Directive (92/43/EEC) assisted these efforts by classifying active (peat accumulating) raised bog and degraded raised bog, capable of restoration, as Annex I habitats for conservation. As a consequence of these actions the Irish Government declared 53 of the largest remaining examples of relatively intact raised bog in the Republic of Ireland as special areas of conservation (SACs), followed by the declaration of a further 75 sites as National Heritage Areas (NHAs).

Despite enjoying legal protection, on-going peat cutting and drainage in the vicinity of both SACs and NHAs, since the implementation of the Habitats Directive(HD) in the early 1990s, has been accompanied by continued loss of uncut peatland. More critically, mapping of plant communities (ecotopes) indicated that the loss of peat-accumulating vegetation on uncut bog was significantly greater, with approximately 40% of central and sub-central ecotope coverage estimated to be lost between 1992 and 2012. (Overall, survey results suggest that although Ireland continues to host over 50% of remaining active raised bog in Western Europe, the current figure constitutes less than 0.5% of the original coverage.) These on-going losses have prompted the European Commission to initiate infraction proceedings against the Irish

Government which could result in annual fines of €9 Million, should current trends in habitat loss continue. To address this issue, and comply with Habitats Directive requirements, the Irish National Parks and Wildlife Service engaged researchers at QUB and RPS Ireland toinitiate an investigative programme aimed at developing national and site specific conservation plans for raised bog SACs and NHAs across the Republic of Ireland, with the aim of developing a national peatland strategy (NPS).

Identification of those areas capable of supporting peat accumulating ecotopes forms a core element of the NPS. Water plays a vital role. Research completed on Clara Bog and Raheenmore Bog in the early 1990s established links between landuse, ecotopes and hydrological processes on Irish Raised Bogs. Critically studies permitted an appraisal of the ecohydrological impacts of marginal peat cutting and/or

drainage on plant communities. Unlike many other hydrological settings, the highly compressible nature of raised bog peat means that changes in pore water pressure, resulting from cutting and/or drainage generate differential subsidence of the ground surface, and an increase in slope approaching a drain. Above a critical slope, peat accumulating vegetation cannot survive. Correlating these topographic conditions with the distribution of plant communities has formed the cornerstone of a GIS-based modelling protocol that permitted hydrological supporting conditions, needed to maintain peat accumulating plant communities, to be constrained.

Since completion of the original ecohydrological investigations, the development of rapid high resolution (LiDAR) surveying techniques has allowed the topographic and hydrological methods to be refined and applied across the country. Incorporating LiDAR survey data with ecotope mapping of SACs and NHAs in a geographical information system (GIS) environment has permitted application of a semi-empirical approach to define how critical topographic conditions vary between locations. Significantly, data analyses demonstrated that slopes necessary to support peat accumulating ecotopes increase moving west across the country; this corresponds to an increase in annual rainfall and rainfall frequency. Critical slopes above which peat accumulating vegetation cannot accumulate (away from zones of focused flow) range from just below 0.3% in the east of the country, to over 0.6% in western transitionalbogs, where conditions begin to grade into western lowland blanket bog.

Benefits arising from application of the GIS modelling tool have proven manifold. Perhaps most significant, in terms of informing the NPS, has been the ability to identify those areas with topographic conditions capable of supporting active raised bog exist, should restoration measures be implemented. Similarly, comparison of ecotope maps with topographic data in areas where restoration programmes have already been applied allows the efficiency of measures such as drain blockage to be evaluated; this in turn provides a basis for developing realistic conservation objectives.

Application of the GIS tool to SACs and NHAs has permitted the definition national and site specific conservation objectives for active raised bog to be placed on a scientifically-defensible footing. This includes identifying those sites, or areas across a site,where the chances of successful restoration prove low to negligible.Following this rationale has permitted application of multiple criteria analysis aimed at replacing those NHAs, where restoration measures were anticipated to provide little to no tangible contribution to national conservation objectives, with non-designated (unprotected) sites having higher conservation value/potential. At a more localized (site-specific) scale, the tool provides a means of screening those areas where peat cutting may continue without damaging site-specific conservation objectives, as specified under Article 6.3 of the HD.This capacity has provided a basis for stakeholder engagement and the ability to identify areas where socioeconomic needs, such as continued peat cutting for domestic fuel, may be considered.

The full benefits of the tool have yet to be realized. These include assessing its utility for identifying those areas of peatland where the uppermost layers of peat have been removed (cutover), but where topographic conditions suggest suitable hydrological supporting conditions for restoration. Given the extent of active raised bog loss in Ireland since the implementation of the HD, and the unlikely ability of existing uncut peatland to meet the restoration shortfall, as stipulated under the directive, this issue will require further study. The tool provides a basis for developing investigation strategies and focusing field work. Overall itprovides an important contribution to decision support systemsfor defining optimal allocation of scarce human and financial resources. In this capacity it provides an important vehicle to help Ireland meet the requirements of the HD, while also considering the needs of local stakeholders.

A TECHNIQUE FOR MODELLING SALINE WATER EQUILIBRIUM IN NATURAL HYDRO-GEOCHEMICAL SYSTEMS

GHANEM Ayman
BOUHLILA Rachida

Laboratory of hydraulics and environmental modelling ,National Engineering School of Tunis, University of Tunis El Manar, BP37, 1002 Tunis-Belvedere, Tunisia, email: aymen.ghanem@enit.rnu.tn

Key words

Hydro-geochemical modelling, brine-rock interaction, Pitzer model, aqueous phase equilibrium

Topic of this work

Geochemical modelling is increasingly playing an important role in various areas of hydro sciences and earth sciences. Geochemical modelling of highly concentrated aqueous solutions represents an important topic in the study of many environments such as evaporation ponds, groundwater and soils in arid and semi-arid zones, brine reservoirs such as Sebkhas, costal aquifers, etc...

We present a new solving technique called SELSAUM -Sels et SAUmures-, developed for modelling thermodynamic equilibrium in complex hydro-geochemical saline systems, and coupled with mass transfer code to perform efficient multiphase-multicomponent reactive mass transport simulations in natural brine hydro-geochemical systems. The algorithm solves the complex heterogeneous phase equilibrium problem in salts and highly concentrated aqueous solutions.

Research question

Modelling the spatial–temporal–chemical evolution of natural aqueous saline geochemical systems requires a reactive mass transport model (a mass transport model coupled with a geochemical model which solves for thermodynamic equilibrium state or simulates reactions kinetics according to the different processes time scales)

Modelling the thermodynamic equilibrium of such aqueous solutions is somehow complex. It requires models based on empirical expansions to take into account these ionic interactions. Several geochemical modelling codes has adopted the Pitzer formulation such as: PHRQPITZ (Plummer et al., 1988), EQ3/6 (Wolery, 1992), PHREEQC (Parkhurst and Appelo, 1999), EQL/EVP (Risacher and Clement, 2001).

Originality of this work

Current hydro-geochemical modelling programs are based upon an approach in which the conservation of total component amounts is combined with a description of chemical equilibrium. One of the biggest issues in numerical implementation of this problem in saline water systems is the numerical scheme used to solve the strongly nonlinear equations system. Most of the cited programs use a

modified Newton-Raphson method and incorporate heuristic methods to overcome convergence problems when the initial guesses of the unknowns are not close to the sought solution values. The new technique is based on a binary search algorithm and it can accurately solve thermodynamic heterogeneous phase equilibrium problem in hydro-geochemical saline water systems. Its numerical performance, and accuracy has been tested. A comparative study of results and with previous works shows a great advantages in terms of calculation speed, accuracy and numerical stability. We have managed to introduce the binary search method to solve a complex hydro geochemical problem more efficiently than any other used method.

Numerical formulation and solving technique

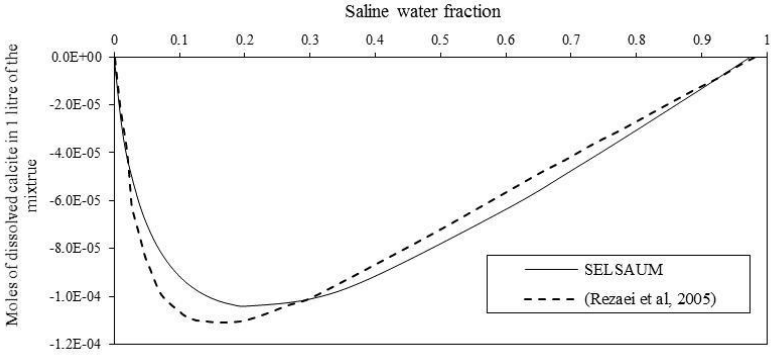
The SELSAUM phase equilibrium problem for a salt-brine heterogeneous geochemical system consists in the calculation of the (unknown) equilibrium speciation and phase assemblage in the system. The system can be mathematically described by three kinds of equations (1) mass-action equations of minerals (product of ionic activity equals mineral solubility); (2) carbonates equilibrium equations; (3) mass balance equations combined with Pitzer equations. The technique is based on a binary search algorithm, this method is widely used in computer science as fast algorithm for searching for a value in a sorted array (Skiena, 2010). It has never been used in hydro-geochemical modelling in any other code. A brief description of the solving technique along with the full numerical problem are presented in the full paper.

Applications, tests and remarks

The technique can be used to compute the equilibrium state of saline hydro-geochemical systems subject to a change. As a testing and comparing procedure we simulated the isotherm seawater evaporation and calcite dissolution in a fresh-salt groundwater mixture. We have simulated the isotherm evaporation of 1 kg of seawater sample at 25°C assuming that the solution is in equilibrium with the atmosphere having a partial CO_2 pressure of $pCO_2 = 10^{-3.5}$ atm during evaporation.

This simulation was carried out over 10^3 steps using tow codes. CPU time was recorded at the end of each step in order to test the present code, results showed that CPU time increases with an increase in the number of included minerals, similar results were obtained for the case of PHRQPITZ. SELSAUM has succeeded to solve the problem of invariant point when gypsum and anhydrite were simultaneously in equilibrium with the solution (description in the full paper).

We also conducted a comparative study between results of computed calcite saturation index and number of moles of dissolved calcite in 1 liter of mixture for different salt-fresh groundwater mixing ratios obtained by this technique and those of (Rezaei et al., 2005).



Dissolved number of moles of calcite in 1 liter of mixture for different fresh-salt water mixing ratios.

The biggest advantage of SELSAUM technique is that it can overcome the problem of invariant points that arises when solving for equilibrium in the occurrence of mineral assemblages constraining water activity or having common components e.g. when gypsum mirabilite and glauberite are simultaneously in equilibrium with the solution. Stability and accuracy of SELSAUM were tested by performing simulation of seawater evaporation and calcite dissolution in fresh-salt water mixture, results of seawater evaporation simulation are qualitatively similar to those obtained by (Risacher and Clement, 2001) and almost identical to those obtained using PHREEQC, results of calcite dissolution in fresh-salt water mixture are also similar to those obtained by (Rezaei et al., 2005).

References

Bouhlila R. 1997. Un modèle de simulation des interactions entre les sels et les saumures. AISH Publications N°255 Hydrochemistry, p. 45-52

Bouhlila R. and Laabidi E. 2008. Impacts of calcite dissolution on seawater intrusion processes in coastal aquifers: Density dependent flow and multi species reactive transport modelling. IASH publication N° 320, pp 148-153

Felmy AR. 1995. "GMIN, A Computerized Chemical Equilibrium Program Using a Constrained Minimization of the Gibbs Energy: Summary Report." Chemical Equilibrium and Reaction Models. Soil Science Society of America, Special Publication 42.

Harvie C. and Weare J., 1980. The prediction of mineral solubilities in natural waters -The Na -K - Mg - Ca - Cl – SO4 – H20 system from zero to high concentration at 25° C. Geochim.Cosmochim. Acta, Vol 44, 981-997.

Harvie C.E., Moller N., Weare J.H, 1984,The prediction of mineral solubilities in natural waters: the Na–K–Mg–Ca–H–Cl–SO4–OH–HCO3– CO3–CO2–H2O system to high ionic strengths at Geochimica et Cosmochimica Acta, 48 (4) (1984), pp. 723–751

Kulik D.A., Wagner T., Dmytrieva S.V., Kosakowski G., Hingerl F.F., Chudnenko K.V., Berner U., 2013. GEM-Selektor geochemical modelling package: Revised algorithm and GEMS3K numerical kernel for coupled simulation codes. Computat. Geosci., 17, 1-24.

Michard G., 1989. Equilibres chimiques dans les eaux naturelles. Ed. Publisud... 123p

Morin. K. A., 1985, SimpliIied explanations and examples of computerized methods for calculating chemical equilibrium in water: Computers & Geosciences, v. 11. no. 4, p. 409-416.

Nordstrom DK, Plummer LN, Wigley TML, Wolery TJ, Ball JW, Jenne EA, Bassett RL, Crerar DA, Florence TM, Fritz B, Hoffman M, Jr G R Holdren, Lafon GM, Mattigod SV, McDuff RE, Morel F, Reddy MM, Sposito G, Thrailkill J. 1979. Chemical Modelling of Aqueous Systems: A Comparison of Computerized Chemical Models for Equilibrium Calculations in Aqueous Systems. Am. Chem. Soc.:, pp 857-892.

Parkhurst, D. L., Thorstenson, D. c., and Plummer. L. N., 1980, PHREEQE-a computerized program for geochemical calculations: U.s. Geol. Survey Water Resources Invest. 80-96. 210 p.

Parkhurst, D., Appelo, C., 1999. User's Guide to PHREEQC (Version2). A Computer Program for Speciation, Batchreaction, One-dimensional Transport, and Inverse Geochemical Calculations. Report 99-4259. U.S. Geological Survey, Denver, Colorado, 312pp.

Pitzer K.S, 1973. Thermodynamics of Electrolytes. I - theoritical basis and general equations, The Journal of Physical Chemistry, Vol. 77, N° 2.

Pitzer K.S. and Kim S.J, 1974. Thermodynamics of Electrolytes IV - Activity and Osmotic coefficients for uniseed electrolytes. Journal of the American Chemical Society.

Plummer L.N., Parkhurst D.L., Fleming G.W, and Dunkle S.A., 1988. A COMPUTER PROGRAM INCORPORATING PITZER'S EQUATIONS FOR CALCULATION OF GEOCHEMICAL REACTIONS IN BRINES U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 88-4153.

Rezeia M, J. Carrera., 2005. « Reactive transport modelling of calcite dissolution in the fresh-salt water mixing zone ». Journal of Hydrogeology. Vol 311, 282-298 p.

Risacher F., Clement A., 2001. A computer program for the simulation of evaporation of natural waters to high concentration, Computers & Geosciences, 27 (2) pp. 191–201.

Skiena, S. 2010. The Algorithm Design Manual (2nd ed.). Springer Science. ISBN 1-849-96720-2.

Stumm W. and Morgan J, 1970. Aquatic Chemistry. An introduction emphasizing chemical. Equilibria in natural waters. Ed Wiley Interscience.

Tulipano, L., 2003. Overexploitation Consequences and Management Criteria in Coastal Karstic Aquifers. IGME, Madrid.

Wigley, T.M.L., and Plummer, L.N., 1976. Mixing of carbonate waters: Geochimica ET Cosmochimica Acta, v. 40, 1976, p. 989-995.

Wolery, T. J., 1992. EQ3/6, A Software Package for Geochemical Modelling of Aqueous Systems: Package Overview and Installation Guide: UCRL-MA-110662-PT-I, Lawrence Livermore National Laboratory, Livermore, California.

Xu, T., E.L. Sonnenthal, N. Spycher and K. Pruess, 2004. TOUGHREACT user's guide: A simulation program for non-isothermal multiphase reactive geochemical transport in variably saturated geologic media. Report LBNL-55460, Lawrence Berkeley National Laboratory, Berkeley, California

RE-DESIGN OF AN OLD FLOOD RESERVOIR BUILT INTO A MULTI-FUNCTIONAL FLOOD RESERVOIR WITH A USAGE OF ECOSYSTEM TECNOLOGIES: A CASE STUDY - 7FP TURAS

Griessler Bulc Tjaša , Faculty of Health Sciences University of Ljubljana and Faculty of Civil and Geodetic Engineering University of Ljubljana, tjasa.bulc@zf.uni-lj.si

Jarni Klara, Faculty of Health Sciences University of Ljubljana and Faculty of Civil and Geodetic Engineering University of Ljubljana, klara.jarni@zf.uni-lj.si

Krivograd Klemenčič Aleksandra, Institute for Water of the Republic of Slovenia and Faculty of

Civil and Geodetic Engineering University of Ljubljana, aleksandra.krivograd@izvrs.si

Key words: ecosystem services, flood reservoir, constructed wetland, ecosystem technology, water pollution, water retention

(1.3 Ecohydrology system solution and ecological engineering for the enhancement of water and ecosystem resilience and ecosystem services)

Topic of this work

In its long history, nature has developed intense self-cleaning and buffering capacities. In the context of ecological engineering, the application of technologies that mimic healthy natural ecosystems became vital. These technologies aim to bring degraded ecosystem back to its equilibrium by closing resource loopand enhance ecosystem services.

Ecosystem technologies (ET) for water management merges vegetated drainage ditches, waste stabilization ponds and stormwater detention ponds, treatment wetlands, buffer zones, phytoremediation with dense woodland establishment, river revitalization, and in stream and bank side river techniques. One of the main aims of ET concept is to integrate exchange, combine and use multi-functionality of different kind of “green technologies” to obtain innovative and sustainable solutions for environmental protection and restoration.

Research question

By applying ET, a local community can play a significant role. In the context of our contemporary environment, it is important to bring sustainability to local communities or to a household level. Pollution originating from local communities can be treated with the use of ET. They can be seen as prophylactic and therapeutic measures to overcome local environmental problems and contribute to human wellbeing. ET include alleviation and adaptation of local communities at a time when climate change affect common life and ecosystem serves became an important decision key in local communities. They could represent an innovative approach towards nature, space and environment

protection based upon system thinking or, in other words, a holistic approach involving technologies aimed at regional and local stakeholder levels.

Originality of this work

The paper presents the case study of a flood reservoir Podutik (Slovenia) built in 1986 and re-designed into a multi-functional flood reservoir (Podutik) with the usage of ET (7FP Turas project). The ET was constructed within Podutik consisting of a constructed wetland and a new river bed with meanders to provide several functions regarding environmental protection and enhanced ecosystem services: a) Flood prevention, b) Water retention for irrigation purposes for urban gardens; c) Water pollution mitigation from urban gardens and sewage overflows; d) Increased self-cleaning capacity of ecosystems; e) Increased biodiversity; f) Establishment of recreation and education path.

Methods

ET efficiency performance was estimated based on the physical, chemical, and microbiological analyses of water on regular base from 2006 to 2014. Algae community composition was determined to assess the ecological status of Podutik, while vegetation and birds were determined to assess biodiversity.

Main results

The efficiency performance of the ET regarding water quality parameters showed that pollutant concentrations met the outflow permitted levels. Biodiversity of algae community in Podutik was high and ecological status of the system was high or good. Vegetation and birds inventory revealed high biodiversity of hygrophilous and marsh plants, and nesting birds. Results show that with the establishment of the ET several ecosystems services have been provided (e.g. water retention and biodiversity).

In the context of sustainable water management, the ET has high ability to mitigate water level fluctuations, has strong remediation ability; provide a higher level of biodiversity and higher stability of ecosystems, which can assure higher resilience to climate change.

Aknowledgements

This work was performed within the framework of the Turas project, financed through 7th Framework Programme of the European Commission, grant agreement no: 282834 and partly financed by Municipality of Ljubljana. The authors are grateful for all the support.

INFLUENCE OF EXTERNAL RESISTOR ON DENITRIFYING ACTIVITY OF A PURE STRAIN OF PSEUDOMONAS STUTZERI IN MICROBIAL FUEL CELLS

L. Jobin , *Institut des Sciences Analytiques UMR CNRS 5280 (ISA), Université Claude Bernard Lyon 1, 5 rue de la Doua, 69100 Villeurbanne, France, lucas.jobin@isa-lyon.fr.*

T. Pommier, *Laboratoire d'Ecologie Microbienne UMR CNRS 5557 (LEM), Université Claude Bernard Lyon 1, 43 boulevard du 11 Novembre 1918, 69622 Villeurbanne, France, thomas.pommier@univ-lyon1.fr.*

C. Jose, *Institut des Sciences Analytiques UMR CNRS 5280 (ISA), Université Claude Bernard Lyon 1, 5 rue de la Doua, 69100 Villeurbanne, France, Catherine.JOSE@isa-lyon.fr.*

J. Gervaix, *Laboratoire d'Ecologie Microbienne UMR CNRS 5557 (LEM), Université Claude Bernard Lyon 1, 43 boulevard du 11 Novembre 1918, 69622 Villeurbanne, France, gervaixjonathan@yahoo.fr.*

Ph. Namour, *Institut des Sciences Analytiques UMR CNRS 5280 (ISA), Université Claude Bernard Lyon 1, 5 rue de la Doua, 69100 Villeurbanne, France, philippe.namour@univ-lyon1.fr.*

Key words: microbial fuel cell, anode redox potential, bacterial metabolic activity, greenhouse gas, self-purification ecosystem service (Topic 4.5 and 1.3 are concerned)

Topic of this work: This work is at the interface between microbiology and electro-chemistry. Microbial fuel cell (MFC) are bio-electrochemical system which implement bacteria to produce electricity. We propose to use it for water bioremediation purpose.

Operational application: This study is part of a Ph. D project aiming at designing a sedimentary microbial fuel cell (SMFC) to promote self-purification process (biodegradation of organic matter) and reduce greenhouse gas emissions in river and sewers. Processes involved are highly dependent on the sedimentary redox potential. This preliminary Ph. D work aims to better understand the relation between the anode redox potential, driven by the external resistor, and the denitrifying activity of a pure microbial strain (*Pseudomonas stutzeri*) in a lab MFC model.

Originality of this work: This first work implements a microbial strain that has never been used in this kind of bio-electrotechnology. *Geobacter sulfurreducens* and Shewanella *Oneidensis* are the most commonly used. Among the denitrifying Pseudomonas, only some of them have been studied in MFCs such as *Pseudomonas aeruginosa*, *P. denitrificans* or *P. alcaliphila*. Few MFC studies focus on how the external resistor (R ext) influences the anode redox potential (ORP) and consecutively the bacterial behavior. Most of the time, implemented systems are complex bacterial consortia whose evolution during MFC culture is hard to apprehend. Moreover, the anode ORP isn't exploited so much in MFC studies. Finally, the link between evolution of bacterial communities and the anode ORP in MFC isn't always clear.

Here, we propose to work on a pure strain for an easier tracking over time of the biological system. As a result, it should be possible to clearly understand the external resistor impact on the current

generated by the microbial strain, and the way the anode ORP is affected according to the ox/red balance. Another important aspect to study is the relation between the anode ORP and the metabolism of *P. stutzeri*. How the denitrifying gas production N_2O/ N_2 evolves depending the anode ORP? The answer of this question represents an important operational interest. Indeed, we plan to use the first results to develop an ORP control strategy based on R ext to influence the microbial activity. The next goal will be to reduce the gas production (CH_4 and H_2S in particular) in more complex microbial systems such as sediments using the ORP strategy previously developed.

Method: *P. stutzeri* will be cultivated in classic "H-shaped" MFCs (two chambers separated by a CMI Ultrex membrane). The culture medium used in the anode compartment is a phosphate-buffered TSB medium. The cathode compartment is filled with phosphate-buffered-deionized water. Anode and Cathode are made of carbon felt, for a respective surface of 21 cm² and 27.7 cm². Three sets of triplicate are used: 3 controls and 6 tests. Reactors are operated at 30°C. Preliminary work is to develop biofilms in each MFCs at fixed external resistors by replacing regularly the culture medium. Current production during biofilms growth is the reference quantity. The latter is monitored thanks to a data acquisition system which enable as well the acquisition of all others relevant electric quantities such as cathode/anode ORP, cell voltage, power output... Then, external resistors are changed and KNO_3 is introduced in the anode chamber of some MFCs so that the strain can start its denitrifying activity. Gas production is monitored by a micro-GC

Main results: This work will be conducted in September. The first results will be presented on the poster if possible otherwise the Ph.D thesis project with the experimental strategy and the first works will be described and discussed.

Acknowledgements: This work is supported by the Agence Nationale de la Recherche (ANR call OH RIQUE 2014) and the Allocation Doctorale de Recherche ARC 2014 (ADR ARC n°3 2014 – n° de

ECOHYDROLOGY FOR RIVER AND MAN SUSTAINABILITY

Edyta Kiedrzyńska, [1)] European Regional Centre for Ecohydrology under the auspices of UNESCO, Polish Academy of Sciences, 3 Tylna Str., 90-364 Lodz, Poland. e-mail: edytkied@biol.uni.lodz.pl;

[2)] University of Lodz, Faculty of Biology and Environmental Protection, Department of Applied Ecology, 12/16 Banacha Str., 90-237 Lodz, Poland.

Marcin Kiedrzyński, University of Lodz, Faculty of Biology and Environmental Protection, Department of Geobotany and Plant Ecology, 12/16 Banacha Str., 90-237 Lodz, Poland.

Maciej Zalewski, [1)] European Regional Centre for Ecohydrology under the auspices of UNESCO, Polish Academy of Sciences, 3 Tylna Str., 90-364 Lodz, Poland.

[2)] University of Lodz, Faculty of Biology and Environmental Protection, Department of Applied Ecology, 12/16 Banacha Str., 90-237 Lodz, Poland.

Key words (5 at the most)

Climate change, catchment processes, wastewater, floodplain and constructed wetlands, ecohydrology

Topic of this work

Every square inch of land on the Earth forms part of a catchment. River catchments with their river valleys, floodplain areas and rivers are crucial hydrosystems that sustain the global freshwater bodies. River catchments in particular are exposed to changes in land use and more pronounced anthropogenic transformation of water and biogeochemical cycles. Rivers and floodplains are situated in landscape depressions, into which a range of substances with anthropogenic modifications and impact are transferred and accumulated, e.g. sediments and nutrients, dioxins and microbial contamination. The dramatically progressing disturbances are often negatively amplified by changes in the hydrological cycle and the loss of integrity between fluvial ecosystems and floodplains, which result in drastically decreased of water quality, increased eutrophication and a reduction in biodiversity and ecosystem services for society.

Research question (or operational application)

European river valleys historically are important ecological corridors and places of economic and cultural development. That is why to achieve a sustainable development it is necessary to harmonize the restoration of degraded river sections and water quality improvement. Therefore, in the face of advancing climate change and against the background of existing demographic trends, there is an urgent need for large-scale testing of integrative scientific solutions.

Originality of this work

This interdisciplinary study of water quality in the Pilica catchment bring new knowledge to foster further scientific development and encourage sustainable social practices. This study can act as a basis

for the management of other river catchments and in turn can contribute to the reduction of eutrophication and degradation of water resources.

Data and / or method

Ecohydrology (EH) is a sub-discipline of Hydrology that focuses on the ecological processes occurring within the hydrological cycle and strives to utilise such processes for enhancing the environmental sustainability of terrestrial and aquatic ecosystems (Zalewski et al. 1997; Zalewski 2011; 2013; 2014). Ecohydrology provides a scientific understanding of the hydrology/biota interplay, and a systemic framework of how to use ecosystem processes as a tool for Integrated Water Resources Management, complementary to ecological engineering and applied hydrotechnical solutions (Zalewski 2014). The key questions posed by EH concern the hierarchy of factors regulating the dynamics of hydrological and biological interactions and the means by which EH can be used to solve environmental and societal problems with reference to Integrated Water Resources Management and in the scope of policies such as the European Water Framework Directive (WFD EC, 2000). The role of Ecohydrology in the implementation of the Sustainable Basin Management and the Water Framework Directive is to facilitate to development of scientific methodologies, whose task is to achieve a ‘‘good ecological status’’ for catchment-river-floodplain ecosystems by stimulating progress in the environmental sciences and enabling a better understanding of their processes.

Main results

The ecohydrological research in central Poland on the Pilica River floodplain assessed the possibilities of enhancing this process, both through and assimilation in the vegetation biomass. The research, based on DTM and hydraulic models, demonstrated that sedimentation of flood sediments in the floodplain essentially reduces their transport to the local lowland reservoir. Flood sediments were effectively deposited and phosphorus was retained in the 30-km section of the Pilica River natural floodplain. In the flooding area of 1,007 ha, fine grained flood sediments reached 500 t and the retention of P was 1.5 t. An ecohydrological study conducted in relation to a hydroperiod showed that the efficiency of nutrient assimilation and biomass production by autochthonous plant communities, with a special emphasis on willow patches, was high. Vegetation in the Pilica River floodplain (26.6 ha) in summer accumulated 255 kg of phosphorus (P) year^{-1}; however, a conversion of 24 or 48 % of the area into willow patches can increase phosphorus retention up to 332 or 399 kg P year^{-1}, respectively (Kiedrzyńska et al. 2008b). Theoretically, 1 kg of P can lead to the accumulation of some 1–2 t of toxic algal biomass in a reservoir. Based on these studies, and the literature, it can be said that river floodplain wetlands are mostly enriched with riverine material and, at the same time, the river water is purified by its deposition. Therefore, river floodplains act as cleaning and biofiltering systems for reducing the concentrations of sediments, nutrients and other pollutants coming from the whole catchment area.

A more proactive approach to environmental river engineering and river floodplain rehabilitation and restoration would have many positive effects for the inhabitants, on both local and regional scales, as would the management of river valleys and floodplains which preserve their potential for water quality improvement and flood prevention, as well as their ecological and aesthetic functions. The exchange of knowledge, experience, and views among scientists, public officials and representatives of industry and business, systematises and integrates our awareness of sustainable watershed and floodplain management is necessary for the identification of problems related to water quality, eutrophication, floods etc., and their solutions.

INTEGRATED SIMULATION OF FRESHWATER BIOTA

J. Kiesel, Institute for Natural Resource Conservation Kiel, IGB Berlin, kiesel@igb-berlin.de
U. Ulrich, Institute for Natural Resource Conservation Kiel, uulrich@hydrology.uni-kiel.de D. Hering, Faculty of Biology, University Duisburg-Essen, daniel.hering@uni-due.de
S. Jähnig, IGB Berlin, sonja.jaehnig@igb-berlin.de

B. Schmalz, Institute for Natural Resource Conservation Kiel, bschmalz@hydrology.uni-kiel.de
N. Fohrer, Institute for Natural Resource Conservation Kiel, nfohrer@hydrology.uni-kiel.de

Key words (5 at the most)

(Sub-topic 1.3)

(hydrology, hydraulics, substrate, integrated modelling, macro-invertebrates)

Topic of this work

The ecohydrologic system forms the basis of freshwater-related processes. These processes act on the catchment and stream scale. We describe the design and application of an integrated, GIS-based model system considering the cause-effect chain from the catchment to the stream and aquatic biota.

Operational application

The presented application example of the developed model system shows the usability and transfera-bility to other ecosystems.

Originality of this work

Models applied for planning restoration measures are mostly targeting individual components of catchment or stream processes; e.g., models might be used just for predicting hydrological or hydrau-lic variables. For a complete consideration of the freshwater ecosystem, both catchment and stream processes need to be represented and linked in integrated simulation approaches. This enables the as-sessment of the impact of global change as well as of more regional and local changes on the stream ecosystem on different scales. The approach is based on the Driver-Pressure-State-Impact-(Response) concept and includes the linkage of one ecohydrologic, two hydraulic and two habitat models.

Data and / or method

The ecohydrologic model SWAT forms the basis of the model system and was used for depicting the discharge regime and erosion processes controlled by land use and climate on the catchment scale. The resulting discharge and sediment time series were used for hydraulic simulations on the reach scale. Water depth, flow velocity, substrate changes and sediment transport were simulated in variable reso-lutions with the hydraulic models HEC-RAS one-dimensionally and with AdH two-

dimensionally. Combined with structural river mapping, the temporally and spatially dynamic results of the hydraulic models were used for describing macroinvertebrate habitats. Two independent simulations were car-ried out: First, the distribution of the freshwater clam Sphaerium corneum was modelled with the spe-cies distribution model BIOMOD, based on parameters related to hydraulics and sediment transport. Second, the Habitat Evaluation Tool (HET) was used to simulate the prevailing macroinvertebrate community in the stream based on the river's substrates. The models require data on climatic and phys-ical catchment properties, on the geometry and structure of the streams as well as species distribution data.

Main results

Model results are maps and statistics of the spatial occurrence of species at different points in time which are connected to the prevailing environmental conditions. Results of the submodels show very good agreement with observed hydrological and hydraulic parameters and good agreement with ob-served spatio-temporal erosion. Simulated spatial species distributions are realistic when compared to observed distributions.

Discussion

The developed model system advances integrated modelling, but future improvements are necessary. This particularly concerns the simulation of abiotic parameters, investigation of organism preferences, the combined simulation of numerous organism groups and the simulation of interactions and feed-back loops.

ROLE OF AFFORESTATIONS ON SOIL WATER BALANCE IN MEDITERRANEAN AREAS

Manrique-Alba, A.[1,2*], Ruiz-Yanetti, S.[1], Moutahir, H.[1,2] ,Chirino, E.[3], Lledó, M.J[1], Bellot,J.[1,2]

[1,2] Department of Ecology and IMEM "Ramon Margalef", University of Alicante, Apdo. 99, 03080 Alicante, Spain
[3] Faculty of Natural Resources, Polytechnic Higher School of Chimborazo, Riobamba, Ecuador
angela.manrique@ua.es

Key words (aquifer recharge, Soil water content, Reforestation, Forest Management)

Water is a limited resource in the semiarid areas, which affects both, the population services (blue water), and the natural ecosystems stability (green water). In this context, an accurate knowledge of soil water balance and role of vegetation cover contribute to improve the management of water and forest resources. These studies are increasingly important, if we consider the latest Assessment Reports of the IPCC. The main objectives of this work are: (1) Determine the soil water balance in two different vegetation types (reforested and not-reforested) and in two different hydrological years (dry and wet), and (2) Assess the effect of management (reforestation) on soil water balance. The knowledge of the role of cover vegetation in water balance is critical as water availability is expected to decrease in the present century. The assessment of the hydrologic variables in forested and not-forested areas is essential for the decision-making process in forest management for semi-arid ecosystems.

Materials and methods

For this purpose we used HYDROBAL ecohydrological model, which calculates at a daily resolution the water flows through the vegetation canopy. In order to achieve these objectives, we selected an experimental site with forested and not-forested areas (3 plots of 100 m^2 each) in the south-east Spain. Soil water balance was calculated in each vegetation type over two hydrological years (2012-2014). Model inputs include climatic variables, soil and vegetation parameters. Model outputs are the principal hydrological variables (interception, net rainfall, runoff, soil water content (SWC), actual evapotranspiration and aquifer recharge). Green water was calculated as the addition of interception and actual evapotranspiration, and blue water was calculated as the addition of runoff and aquifer recharge. The model calibration and validation can be performed by using observed runoff, soil water content or direct percolation. In this case, the calibration was done by means of Montecarlo simulations using observed soil water content from the first year. The validation was done by a linear adjust between simulated and observed data from the second year.

Results

The validation of Hydrobal model shows a good fit (SWC observed vs. SWC estimated by model) in reforested and in not-reforested areas (R^2=0.78; R^2=0.88 respectively), generating acceptable errors (RMSE:1%), and statistically significant in both case (p value < 0.001). The model shows different results, due to the role of vegetation and annual rainfall (figure 1). The results indicate that interception is a determinant factor in the water balance, reducing significantly the amount of net rainfall. Higher values of interception were observed in reforested areas (31 and 40% for wet and dry year respectively), meanwhile lower values were observed in not-forested areas (21 and 30% for wet and dry year respectively). The small values of runoff estimated for both years, did not

differ between both vegetation types. Actual evapotranspiration represents an important part of the water balance (43-52%). Nevertheless, it didn't show differences between the two vegetation types in the wet year, but it was higher in not-reforested area in the dry year (52%). In the wet year, the percentage of aquifer recharge (25-29% of annual rainfall) was higher than in the dry year (7-10%). The obtained results offer relevant information regarding the role of vegetation cover (green water), which represents 75% and 65% of the water balance in reforested and not-forested areas respectively for the wet year. Moreover, according to the results in the dry year these were higher in both cases 87% and 82% for forested and not-forested areas respectively.

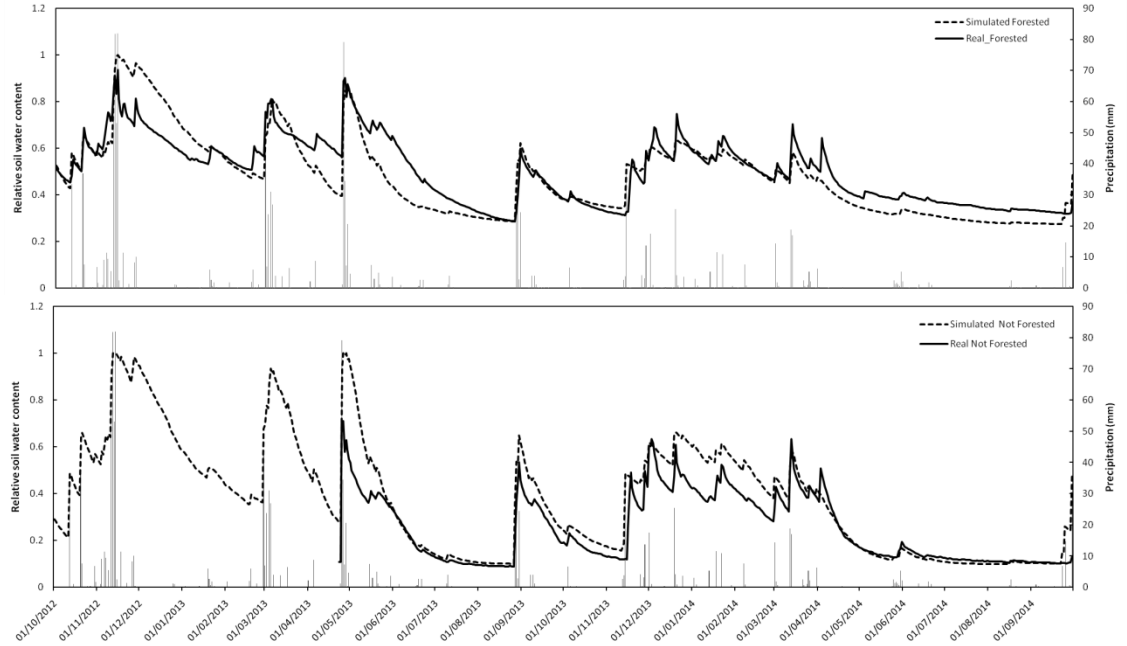


Fig.1-Daily mean values of SWC expressed as its proportion over field capacity(SWC/FC), for simulated and real values in each vegetation type during the entire study period.

Conclusion

The Hydrobal model was successfully implemented to quantify aquifer recharge, showing good fits. Vegetation cover and annual rainfall determined the difference in soil water balance. Results indicate that landscape with lower vegetation stratum and cover provide higher aquifer recharge. In addition, for dry years the ratio *green/blue* water show higher values, this situation is expected to be accentuated due to climate change.

Aknowledgements

This work has been supported by the Spanish Ministry of Economy and Competitiveness trough the project ECOBAL (CGL2011-30531-C02-01). A. Manrique-Alba also acknowledges to this Ministry the FPI grant to perform her PhD. E. Chirino thanks the Prometheus Project (SENESCYT, Ecuador) for funding his grant.

Universitat d'Alacant
Universidad de Alicante

INSTITUTO MULTIDISCIPLINAR PARA EL ESTUDIO DEL MEDIO Ramon Margalef

ROLE OF AFFORESTATIONS ON SOIL WATER BALANCE IN MEDITERRANEAN AREAS

Manrique-Alba, A.[1,2*], Ruiz-Yanetti, S.[1], Moutahir, H.[1,2], Chirino, E.[3], Lledó, M.J[1,2], Bellot,J.[1,2]

*Angela.manrique@ua.es

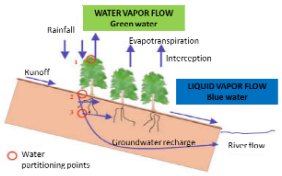
[1,2] Department of Ecology and IMEM "Ramon Margalef" University of Alicante, Apdo. 99, 03080 Alicante, Spain
[3] Faculty of Natural Resources, Polytechnic Higher School of Chimborazo Riobamba, Ecuador
[4] Joint Research Unit University of Alicante-Foundation CEAM, University of Alicante, Apdo. 99, 03080 Alicante, Spain

EcoHydrology 2015 Lyon, France, from 21 to 23 September

INTRODUCTION

Water management is an important concern in semiarid areas. A sustainable future depends on the ability to manage trade-offs between human needs **(blue water)** and natural ecosystems stability **(green water)**.

In this context, the assessment of the hydrologic variables in pine afforestations and not forested areas is essential for the decision-making process in forest management.

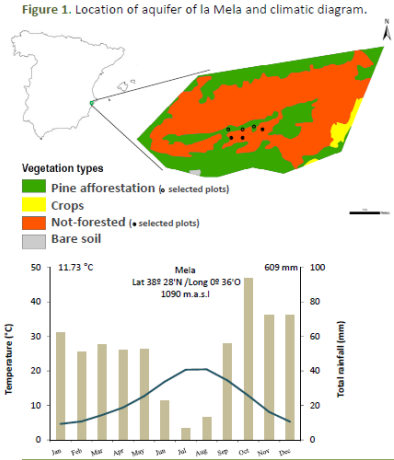


OBJECTIVES

1. To determine the soil water balance in two different vegetation types (reforested and not-reforested) and in two different hydrological years (dry and wet).
2. To assess the effect of management (afforestations) on soil water balance.

MATERIALS AND METHODS

Figure 1. Location of aquifer of la Mela and climatic diagram.



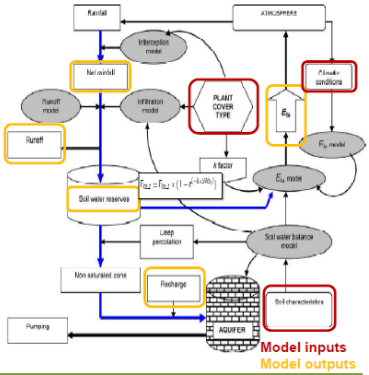
We used HYDROBAL **(figure 2)**, an eco-hydrological model for assessing water balance, it has been applied successfully to analize the soil water balance on different vegetation cover types **(table 1) [2][3].**

Table 1. Main Vegetation Characteristics

Vegetation cover	Canopy cover (%)	Height (m)	LAI ($m^2 \cdot m^{-2}$)
Pine Afforestation	77	6.68	1.96
Not Forested	90	0.9	1.47

Soil water balance was calculated in each vegetation type over two hydrological years (2012-2014). Calibration was done using observed soil water content (SWC) from the first year. And validation by a linear adjust simulated *vs* observed data from the second year **(figure 3)**.

Figure 2. HYDROBAL model operation **[1].**



RESULTS AND CONCLUSIONS

Vegetation cover and annual rainfall have an important influence on the green/blue water ratio **(figure 4, Table 2)**. In dry conditions the major part of water inputs are destined to meet the vegetation needs.

Table 2. Ratios green/blue water.

Ratio	Wet Year	Dry year
Pine Afforestation	2.9	11.6
Not Forested	2.2	8.2

Figure 3. Daily mean values of SWC expressed as its proportion over field capacity (SWC/FC), estimated and observed values in each vegetation type during the entire study period. The validation shows good fits in pine afforestation and not forested areas (R^2=0.78; R^2=0.88 respectively, RMSE 1%), statistically significant in both cases (p value < 0.001).

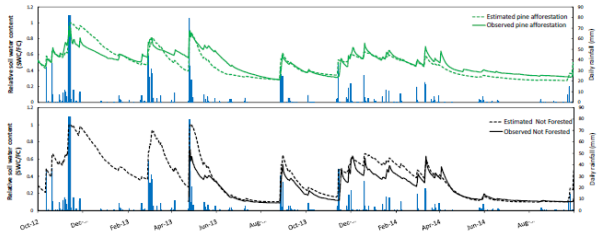
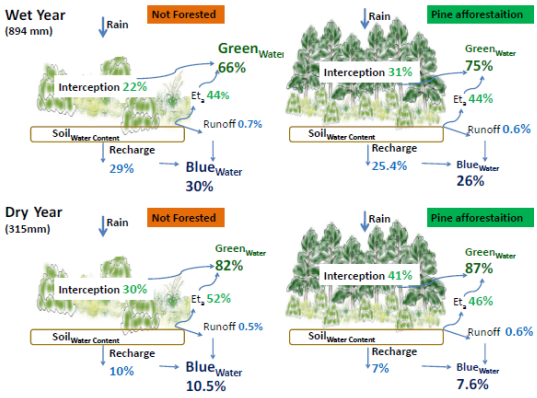


Figure 4. Results of HYDROBAL water balance.



Hydrobal model was successfully implemented to quantify water flows, showing good fits. For dry years the ratio green/blue water show higher values, and differences between Not forested and Pine afforestation areas increase. This situation is expected to be accentuated due to climate change.

ACKNOWLEDGEMENTS

This work is supported by the Spanish Ministry of Economy and Competitiveness trough the project ECOBAL(CGL2011-30531-C02-01). Manrique-Alba also acknowledges to this Ministry the FPI grant to perform her PhD. Chirino thanks the Prometheus Project (SENESCYT, Ecuador).

[*] The HYDROBAL model can be provide to interested persons for free.

REFERENCES

[1] J. Bellot, E. Chirino. Hydrobal: An eco-hydrological modelling approach for assessing water balances in different vegetation types in semi-arid areas. Ecological Modelling 266 (2013)
[2] I. Touhami, J. M. Andreu, E. Chirino, J. R. Sánchez, H. Moutahir, A. Pulido-Bosch, P. Martínez-Santos and J. Bellot. Recharge estimation of a small karstic aquifer in a semiarid Mediterranean region (southeastern Spain) using a hydrological model. *Hydrol. Process.* 27, (2013)
[3] I. Touhami, E. Chirino, J.M. Andreu, J.R. Sánchez, H. Moutahir, J. Bellot. Assessment of climate change impacts on soil water balance and aquifer recharge in a semiarid region in south east Spain, Journal of Hydrology (2015)

THE ALGAL LIFT – BIOGENIC SEDIMENT TRANSPORT

Clara Mendoza-Lera [1,2] cmendozalera@hotmail.es
Laura L. Federlein[2] laura_federlein@hotmail.de
Matthias Knie[2] knie@b-tu.de

Michael Mutz[2] m.mutz@b-tu.de

[1]IRSTEA, 5 rue de la Doua CS70077 69626 VILLEURBANNE Cedex, France

[2]Brandenburg University of Technology, Department of Freshwater Conservation, Seestraße 45, D-15526 Bad Saarow, Germany

Key words (5 at the most)

(subtopic 2.1)

sediment dynamics, buoyancy, floating algal mats, benthic-pelagic coupling, flume experiments

Topic of this work

One of the most interesting challenges of ecohydrology is to understand and estimate the significance of reciprocal influences of hydrology and the stream community for ecosystem functioning.

In streams, sediment transport dynamics modulate the vertical water exchange and, in turn, ecosystem functioning (i.e. metabolism and nutrient cycling). Algal mats influence reciprocally sediment transport dynamics by means of sediment biostabilization. The metabolism of the algal mats can produce gas bubbles (e.g. oxygen or methane) that accumulate in the mats and/or sediment pores. This accumulation of gas bubbles increases the buoyancy of the algal mats and eventually causes their detachment to form floating algal mats that drift downstream. Such floating mats have been observed in rivers and streams but also in litoral zones of lakes and shallow water bodies. However, the potential of this detachment to transport sediment and, in turn, disturb the uppermost sediment layer remains unclear and, to our knowledge, has not been reported before.

Research question (or operational application)

Do the algal mats have the potential to transport sediment?

Does the sediment transport potential vary with varying grain sizes?

Originality of this work

This research presents a novel finding which to our knowledge has not been reported before: algal mat mediated biogenic sediment transport during low-flow periods. During such periods, currently seen as non-dynamic, sediment dynamics could be promoted by biogenic processes. In addition to the

mechanism of sediment transport, the detachment causes heterogeneity at the upper sediment layer and has the potential to alter superficial clogging layers affecting the vertical water exchange and, subsequently, influences ecosystem function and services associated with the bed sediments.

Data and / or method

We tested the potential of algal mats to lift sediments in 12 indoor flumes filled with sand (0.2 – 0.8 mm), gravel (2 – 8 mm) or a sand-gravel mixture (25/75 % mass). We run the flumes for 37 days. Throughout the experimental time we measured the development and coverage of algal mats. When the detachment occurred at day 32, we collected the algal mats to determine the detached biomass and the amount of sediment transported.

Main results

After 28 days, the algal mats covered about 50 % of the flumes. Due to the accumulation of oxygen gas bubbles in the mats that developed from high primary production, about half of the algal mats detached from the bed carrying entangled sediments (day 32). The area covered by algal mats was similar among sediment types, but the amount of sediment particles transported was higher for sand and sand-gravel mixture compared to gravel. The disruption of streambed relief was much higher for sand and sand-gravel mixture, than for gravel.

Conclusion

Our results reveal a novel mechanism of biogenic sediment transport which can cause sediment transport dynamics during low-flow periods. Additionally, the detachment of mats from sandy streambed disrupted the upper sediment layer, which is often clogged. Hence, in sandy sediments the „algal lift" has the potential to disrupt superficial clogging layers (i.e. "de-clogging") and to increase the vertical water exchange and consequently the ecosystem functioning.

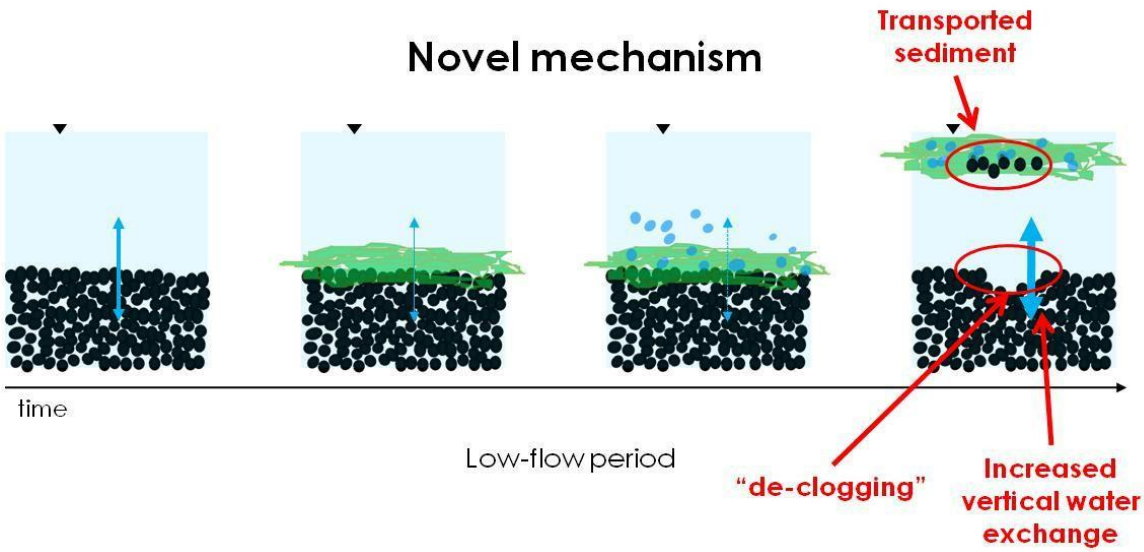


Figure. Graphical abstract. Blue arrows represent the vertical water exchange and its thickness the rate.

PLANTED DETENTIVE FILTERS FOR TREATING COMBINED SEWER OVERFLOW

Tamás Gábor Pálfy[abc], Daniel Meyer[a], StéphaneTroesch[b],

RémyGourdon[c], Pascal Molle[a]

[a]WaterQuality and Pollution PreventionResearch Unit, IRSTEA Lyon, 5 rue de la Doua Villeurbanne, 69626 France (tamas-gabor.palfy@irstea.fr)

[b]Epur Nature SAS, 153 Avenue Marechal Leclerc, Caumont sur Durance, 84510 France (stephane.troesch@epurnature.fr)

[c]INSA Lyon, Laboratoire de Génie Civil et Ingénierie Environnementale, 20 avenue A. Einstein, Villeurbanne, 69621 France (remy.gourdon@insa-lyon.fr)

Key words: constructed wetlands, stormwater treatment, combined sewer overflow, planted detentive filters(1.4 Urban Ecohydrology – storm water purification and retention in the city landscape, potential for improvement of health and quality of life)

Topic of this work

Design and operation optimization of planted detentive filters (PDFs). These species of vertical flow constructed wetlands are variably saturated (event triggered)and applied for stormwater treatment.

Research question (or operational application)

How can PDFs be optimized in terms of scaling and operation?

How effective are PDFs in pollutant removal for combined sewer overflow (CSO) application?

Originality of this work

PDFs are applied to treat separate sewer outlet or CSO. They efficiently reduce negative impacts on receiving waters by filtering suspended solids,removing organics and ammonium and detaining flow peaks. The first full-scale CSO system of France was built at Marcy l'Etoile based on experiences from Germany[1], from 'French design' CWs treating municipal wastewater[2] and pilot-scale research[3]. The site has innovations such as i) the coarser media tolerates loadings without pre-treatment thus the need for sludge management is less frequent, ii) the bottom of the filter is permanently saturated to prevent drought stress on reeds at dry periods, iii) the aeration pipes are placed above the permanently saturated zone, iv) the media contains zeolite for higher ammonium removal, v) the priority of feeding on the dual filter basin is alterable which enhances sludge mineralization when events are frequent, benefiting performance and extending life cycle.

The stochasticity of flows andpollutant concentrations and the periodicity of storm events are making the optimal scaling of PDFs challenging. We introduce PDFs and their pollutant removal mechanisms.

We demonstrate the monitoring strategy and our first resultsfrom automatic sampling of flows.We also show how the data from the site will be combined with process-based modelling to create and calibrate the design-support softwareOrage which will enable engineers to deal with stochasticity.

[1]Uhl, M., Dittmer, U. 2005.Constructed wetlands for CSO treatment: an overview of practice and research in Germany.*Wat. Sci. Tech.* 51(9), 23-30.

[2]Molle, P., Liénard, A., Boutin, C., Merlin, G., Iwema, A. 2005. How to treat raw sewage with constructed wetlands: an overview of French systems. *Wat. Sci. Tech.* 51(9),

[3]Fournel, J. 2012. Extensive systems for the treatment of urban stormwater [in French].*Systemes extensifs de gestion et de traitement des eaux urbanies de temps de pluie*. PhD dissertation, IRSTEA, France, 217 pp

Data and / or method

The siteis monitored to 1) gain performance data, 2) improve the design and 3) to calibrate Orage. The monitoring includes measurement of the inflow rate and the outflow rate by filter side. The flows are composite sampled for TSS, total COD, dissolved COD, NH4-N, NO3-N and PO4-P. Online probes were installed by filter outlet for minute-based NH4-N and NO3-N measurement. Pressure probes and TDR probes are installed in the filter to combine measurements with process-based modelling experiments.

Main results

We introduce PDFs and pollutant removal mechanisms as well as the monitoring methods and first results from automatic sampling of flows. Twelve high-load feeding events (1–14 m3/m2 filter surface) were investigated. Fig. 1 shows removal performances for these events. Several of them represented extreme pollutant loads compared to the design load of the wetland:

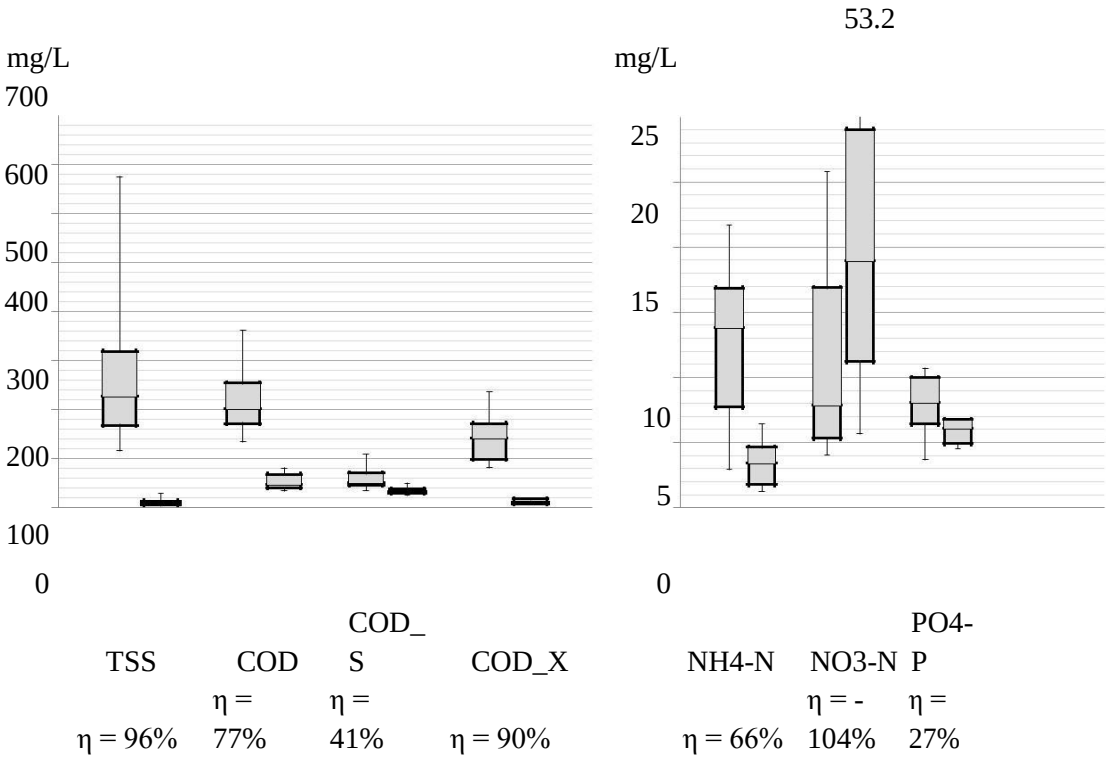


Figure 1: In- and outflow concentrations by pollutant on boxplots and average mass removal performances(η). Left plot: inflow, right plot: outflow and by pollutant. N=12-16 events. Whiskers represent 10th and 90th percentiles.

Results show high treatment performance: SS were filtrated from 75–800 mg/L to a background concentration below 30 mg/L. Total COD (inflow 60–1500 mg/L, outflow < 100 mg/L) and dissolved COD (inflow 30–400 mg/L, outflow < 60 mg/L) were strongly decreased even after long ponding periods. Inflow NH4-N concentrations up to 28 mg/L were reduced to 1–7 mg/L.

Conclusions and outlook

The monitoring results show that the applied technology at Marcy l'Etoile PDFis a reliable state-of-the-art best management practice.The monitoring and the software development of Orage are continued. The first calibration and sensitivity analysis of its core model is on schedule based on field measurements.

CHARACTERIZATION OF DISSOLVED ORGANIC MATTER IN VOSGES MOUNTAINS HEADWATERS

M.N. Pons, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

M. Dasle, S. Pontvianne, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France
F. Guérold, P. Wagner,Laboratoire Interdisciplinaire des Environnements Continentaux (UMR 7360 CNRS), Université de Lorraine, Campus Bridoux, Rue du Général Delestraint, 57070 Metz cedex, France

A. Legout, Biogéochimie des Ecosystèmes Forestiers, Route d'Amance, 54280 Champenoux, France

Key words (5 at the most)

Acidification, Dissolved organic matter, Synchronous fluorescence (4.1, 2.5)

Research question (or operational application)

Forests provide numerous ecosystemic services such production of high quality water. With more than 850 000 ha, forest covers 36% of the Lorraine region in North-East of France. 34% of these forests are located in the Vosges Mountains. They are crossed by a dense river network which feeds the Upper Moselle watershed. The Vosges Mountains constitute a large water-tower in the North-East of France. In spite of a reduced anthropization the quality of the surface water in many sectors is problematic: decades of atmospheric deposits have acidified soils and surface water. Acid water facilitates metals (aluminum, arsenic, manganese) dissolutionandjeopardize the drinking water production.

Originality of this work

As part of a project of long-term monitoring of the resilience of Vosges Mountains river heads, the relation between aluminum and organic carbon (i.e. humic substances) has been investigated since Sept 2011.The paper focused on the characterization of organic matter by optical methods, namely, UV-visible spectroscopy and synchronous fluorescence spectroscopy.

Data and / or method

Since 2011 sixteen Vosges Mountains river heads, running on sandstone or granite are collected monthly and analyzed for their dissolved organic matter as well as mineral content (Ca, Mg, Na, K, Al, chlorides, sulfates and nitrates).Some other streams are used for comparison and scanned less frequently. Total dissolved organic carbon is measured. Absorbance spectra as well as fluorescence synchronous spectra (with a 50 nm gap between excitation and emission) are collected. For some series, emission spectra for excitation at 254 nm and 370nm have also been collected.

Data and / or method

For the different samples absorbances at 254 and 280 nm wavelengths are compared with DOC. The maximum of the second derivative (usually around 225 nm) is correlated with the nitrates. FI and HIX indices are extracted from the 254nm and 370nm emission spectra. Synchronous fluorescence spectra are either compared using Principal Components Analysis (without any assumption on the number of fluorophores present in the sample) or in terms of pseudo-components after decomposition of the spectra into a series of Gauss functions. Usually up to five Gauss functions are required: one for protein-like fluorescence, two to three for humic substances fluorescence and one related to chlorophyll pigment.

Main results

As an illustration of the results, Figure 1 compares the decomposition into three Gauss functions (λ_{ex} 280 nm (A), 330 nm(B) et 370 nm (C)) for the samples collected in July 2014 in the Vosges Mountains. Although there are variations with respect to time, each stream seems to exhibit some steady trend in terms of the relative importance of the different fluorophores (Figure 2).

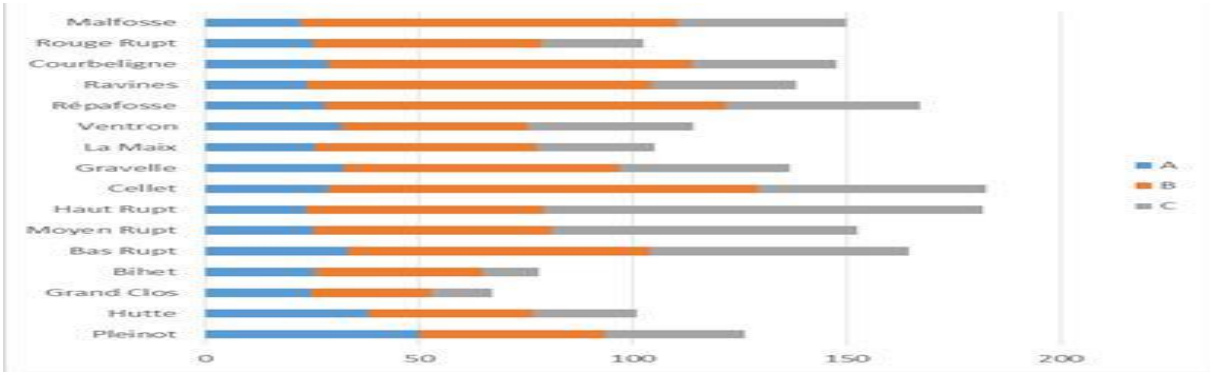
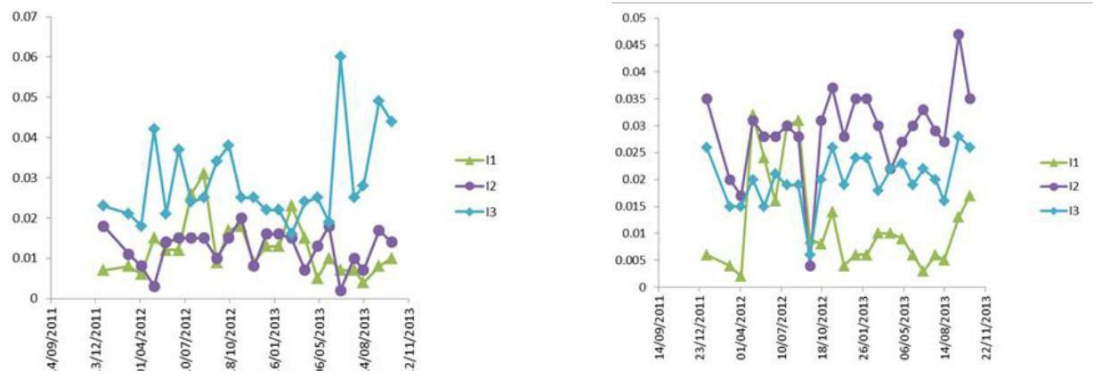


Figure 1: Concentrations in fluorophores A, B and C in July 2014



Haut Rupt Cellet

Figure 2: Variation with respect to time of the fluorophores concentrations in the Haut Rupt and Cellet streams

MAKING THE BEST USE OF ECOLOGICAL AND EFFICIENCY INDICATORS TO GUIDE FLOOD RISK PROJECT

MANAGEMENTPOSTER 1: USING IMPROVED RIVERSCAPE CONCEPT FOR DESIGN STAGES ;
POSTER 2: EVOLUTION OF INDICATORS FOR DECISION MAKING AT DIFFERENT STAGES.

Christine Poulard, Pascal Breil:Irstea, UR HHLY, 5 rue de la Doua CS 70077, F-69626 Villeurbanne Cedex, France (firstname.lastname@irstea.fr)

Michel Lafont,formerlyIrstea / Les Jardins d'Artémis, F-69100 Villeurbanne, michel.lafont33@sfr.fr André Evette, Irstea, F-38402 Saint Martin d'Hères Cedex,France ;andre.evette@irstea.fr

Laurent Schmitt, Université de Strasbourg, Faculté de Géographie et d'Aménagement, Laboratoire Image Ville Environnement UMR 7362 Unistra-CNRS-ENGEES ; 3 rue de l'Argonne, 67083 Strasbourg cedex Strasbourg, France ;laurent.schmitt@unistra.fr

Régis Vivien, Swiss Centre for Applied Ecotoxicology (Ecotox Centre), Eawag/EPFL, 1015 Lausanne, Switzerland ;regis.vivien@centreecotox.ch
Mélanie Laluc, BURGEAP, 19 Rue Villette, F-69003 Lyon ,France ; m.laluc@burgeap.fr

Key words

Flood mitigation, multiobjective strategy, MCA, co-conception, riverscapes

Subtopics [1.1][1.3]

Introduction

"Flood control" policies have now shifted to "integrated flood risk management", which should also blend nicely within "water management" and "sustainable development". Thus, flood risk reduction strategies are one element to define in coordination with others in a broader picture. From a practical point of view, the relevance of flood management projects must now be examined under several angles.

This is where Multi-Criteria Analysis is useful: they assess objectively the impact of projects through different indicators, either to guide decision-makingby the project manager, or even to obtain final authorizations and/or funding. Here, we advocate that it could be used as guidance throughout all the stages of the project, to ensure informed decisions at each step, from the definition of the project broad lines to the choices of technical details. This means that we need tools and indicators to help people with different backgrounds and objectives, not necessarily used to working together(e.g. hydrologists, ecologists, geomorphologists, planning managers including urban planning, citizens...), to define common objective and improve collectively technical solutions.We propose here a practical method to

define the best compromise between the different disciplines involved by the project, and all along the process.

Material and methods

The first step was a feed-back analysis of dry dams (Poulard*et al*., 2009), which showed a great diversity of technical solutions for the same objective (dam mitigation), and led to the question of the respective impact of each design on the river aquatic ecosystems. From this material, we tried to define a metrics of the impact of anthropizationon the river biodiversity and ecological functions in a Polish catchment (Poulard*et al*., 2010). For this, we used a pragmatic typology based on riverscapes (Malard, 2006), summarizing relevant information for all possible types -natural and artificial:we suggested to measurethe impact of structures by the shift in riverscape type: from the riverscapes before the project, to the riverscapes once the dam built. This metrics, even if only qualitative, can guide technical choices. To facilitate the emergence of good technical solutions, we suggested a way towards a compromise:for each part of the dam, the riverscapeshift due to different variants is assessed: the solution that meets civil engineering and hydrologic requirements and causes the lesser shift is the best . However, this first application in a homogeneous context (similar rivers, little diversity of structures) led to a well-hierarchized, simple typology: obviously further developments were required for more complicated cases.

We then proposed to generalize the approach from dry dams to any other feature modifying a river, for flood mitigation or restoration (Poulard*et al*., 2011).Lafont (2011) suggested using Functional Units to define riverscapesin more details (Table 1). Poulard*et al*. (2013) proposed to enrich the description of the riverscapes with features of the adjacent terrestrial ecosystems (presence/absence of riparian zone…) and to complete the individual diagnostics for each projected modification with a global diagnostic at the scale of the whole studied domain, in terms of diversity and spatial coherence.

POSTER 1 presents further improvements to this approach:we nowconsiderthe terrestrial ecosystems,where relevant, as independent entities ; we propose to coin the word “terrascape” on the model of our riverscapes descriptions. Riparian ecosystems show a high level of biodiversity, partly controlled by flood regime through disturbance and flow of diaspores (Junk *et al.* 1989, Merritt*et al*. 2010). Works from Cavaillé*et al*. (2013) on riverbank protections could serve as basis to define riparian terrascapes. Even fullyterrestrial ecosystems can be integrated in the study when impacted by floods, sometimes severely (e.g. Koutecký and Prach 2005), or by flood mitigations structures. For instance, the water level upstream dry dams rises dramatically during floods, which damages the terrestrial ecosystems in dry dam bowls.

POSTER 2presents a framework to place this approach in a coherent process, from specification writing to assessment. Indeed, our previous works were focused on the design stage, after the type of actions is already chosen (dry dams), and only variant of technical solutions are examined, within the same range of costs and efficiency. In a context of integrated management, it appears now necessary to start co-conception earlier. This second poster therefore presents a framework to guide decision-making at all stages, using Multi-Criteria Analyses.

Theory

Rethinking the approach to better fit it in the context of actual project led us to:

Poster 1:
Refine the principles of our approach and improve description of riverscape types:
we propose, as support for discussions, synthetic descriptions of every natural and artificialized conditions in the form of “riverscapes”and “generalized -scapes” where relevant, understandable by everyone involved. Riverscapes with a code “0” are (near-)natural types present in the studied domain ; they constitute a reference, whether ecologically good or poor. Riverscapes derived from a reference type are named after it, with a code increasing with the level of degradation.

The measure of impacts of proposed actions is the subsequent shift of types;
each implementation will lead to a different description of types and of evolution indicators, depending on the natural context, the objectives of the project and the types of actions to be assessed. They must be tailor-made in concertation to help people understand each other, define common solutions and collect and integrate suggestions from different specialists ;

Poster 2:
Linkthe indicators with those of the MultiCriteria Analyses assessing the final project.
the discussions are to take place throughout the project, from the choice of the general orientations to the design of each action, including technical details when relevant. The idea is to define for each stage an adapted MCA, suitable for discussions, while ensuring coherence between the stages, always keeping in sight the final MCA, requested by the project manager or external authorities. In this framework, poster 1 corresponds to one of the stages of the process.

Results

Poster 1:

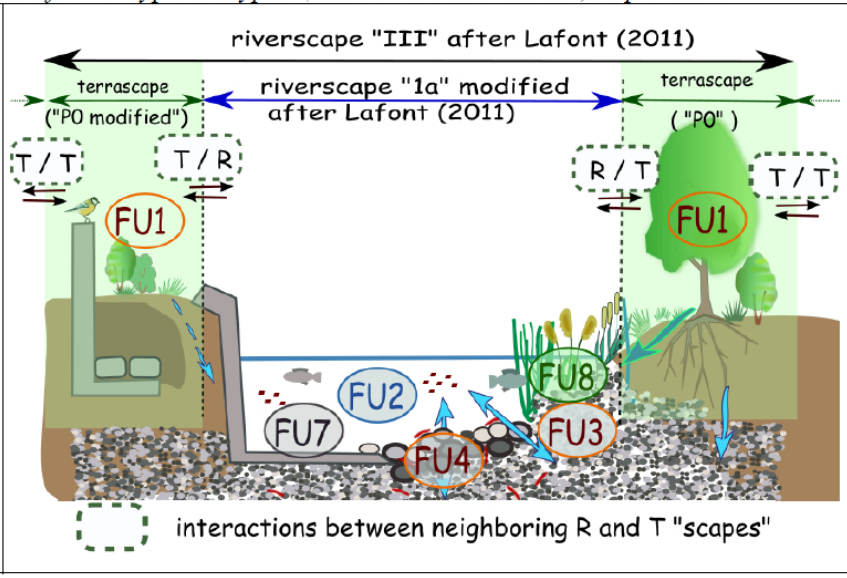
Physical characteristics	*semi-natural conditions 1a:30 to 50% artificial ; 1b: 50 to 70 % artif. Surface Water / Ground Water (SW/GW) connections partially restored*
processes	*Metabolic processes of increasing diversity compared to type 2 (100% impervious, no SW/GW exchanges).The porous matrix fully acts as a filter (FU3, FU4).* ***Type 1b****with sandy or fine sedimentdeposits (FU5, FU6)* ***Type 1a****has better SW/GW exchanges,and macrophyte assemblages (FU8)*
Biomonitoring indices suited to this type (here, French indices)	*Biomonitoring may be performed using diatom indices,oligochaete Functional Traits, macrophyte indices, IOBS index and harmonization system. Traditional invertebrateindices and fish index can be used, but mainlyin* ***type 1a*** *which is coming closer to a "natural"system. The use of geomorphological reference types(Schmitt et al. 2006; 2011) might be indispensable whenthe physical restoration from a type 1 totype0 (near natural or natural) is planned.*
Schematic cross-section with Functional Units: example of ***1a*** *FU1: interactions terrestrial / aquatic environments; FU2: water mass; FU3: coarse sediments; FU4: hyporheic porous matrix; FU7: flat system (boulders, impervious material); FU8: macrophytes*	

Table 1:new description of a riverscape, based on functional units, where terrestrial units (FU1) are excluded to be addressed separately as "terrascapes" ; modified afterLafont (2011), Differences with better type (0) and more degraded (2) are explicitly mentioned and described.

Table 1 shows a riverscape described by Lafont (2011)using Functional Units. We sketch in table 2 how "terrascapes" could be defined. Features which discriminate a riverscape reference type from the others, or a degraded form from the others, must be put forward ; common features can be omitted (e.g., the soil type is not detailed here, but could be relevant in other cases).

To prepare the assessment of local modifications, the possible shifts from the natural type (P0) to more degraded types are described, whether by hydraulic works (P1) or human activity (A). To help the global assessment, positive and negative interactions with other "scapes" are also very important, whether with adjacent areas or beyond (for instance,dry dam modify the flood regimes and subsequently sediment transport over a long reach downstream).

Table 1:new description of a riverscape, based on functional units, where terrestrial units (FU1) are excluded to be addressed separately as "terrascapes" ; modified afterLafont (2011), Differences with better type (0) and more degraded (2) are explicitly mentioned and described.

Physical characteri	***P0****(natural riverine habitat):****simple description: "****characterized bypatches of habitats, trees + bushes + grassed areas" ;* ***finer specialized description (…),***

stics of "P" type (and subtypes)	***P1:*** *natural landscape like P0 but located within a dam bowl:subjected to enhanced flood hazard (water stored for a longer time and with high water depth ; possible sediment deposit…).* ***Possible shifts****: P0 <=>P1(construction/removal of a dry dam) ; P0, P1<=>**A**(A=agricultural area outside dam bowl, Ab =within dam bowl…)*
Links with other "scapes"	***Positive interaction****of P0 and P1:* • *(+) with the other nearby natural patches (connected better than isolated)* • *To the river: (+) P0 and P1: input of organic matter, shade ; (-) Ab: possible pollution of cultivated land by chemicals or fine sediments* • *(+) From the river to types P: water, food for birds*
Represent ative photos	 *P1 in normal state vs flooded conditions*  *P1:blocks deposited after flood event*

Table 2: Possible description of "terrascape"type and sub-types suited for a dry dam bowl

Poster 2:
Our previous works focused on dry dams, and concertation consisted in choosing the

"best attainable riverscapes", to reduce the negative impacts on the river. Poster 2 proposes to generalize the concertation process, from earlier stages (choice of action) and ensure compatibility with the final multi-criteria assessment. Our working hypothesis is that multi-criteria analysis can provide a good framework for decision-making at all stages. To improve a project, the scores for every criterion are useful:a total score would hide the specificities. Radar graphs appear very appropriate to display these results in a synthetic way, and thus discuss and compare solutions (e.g. Edjossan-Sossou*et al.,* 2014.). Table 3 gives an idea of how MCA could be used and adapted throughout a project, from to definition of the project to the design stages.

The prerequisite is an explicit list of the project manager's objectives (stage1).They should be compatible with the local and national policies when relevant, and comply with the requirement from authorities or funding institutions.In the early stages, we need a very pragmatic and simplified form of MCA. As the project progresses from one stage to another, criteria are refined, other are removed because they are insensitive to the remaining choices, but always in good agreement with the other stages, in particular with the MCA used to assess the final project (for internal decision-making and/orto obtain authorizations or funds).Table 3 tackles practical problems: how to define the minimum and maximum for each criterion (absolute or relative values ? how to account for uncertainty ?…) ; the examples shown here illustrate the issue but of course in each case the choices have to be made by the people involved in the project. Poster 1 deals with stage 3, after the actions are chosen (dry dams, in our case); the impact of individual actions are measured by the shifts in riverscapes. We added here an indicator of the overall impact at the scale of the catchment, based on the respect of green and blue networks.

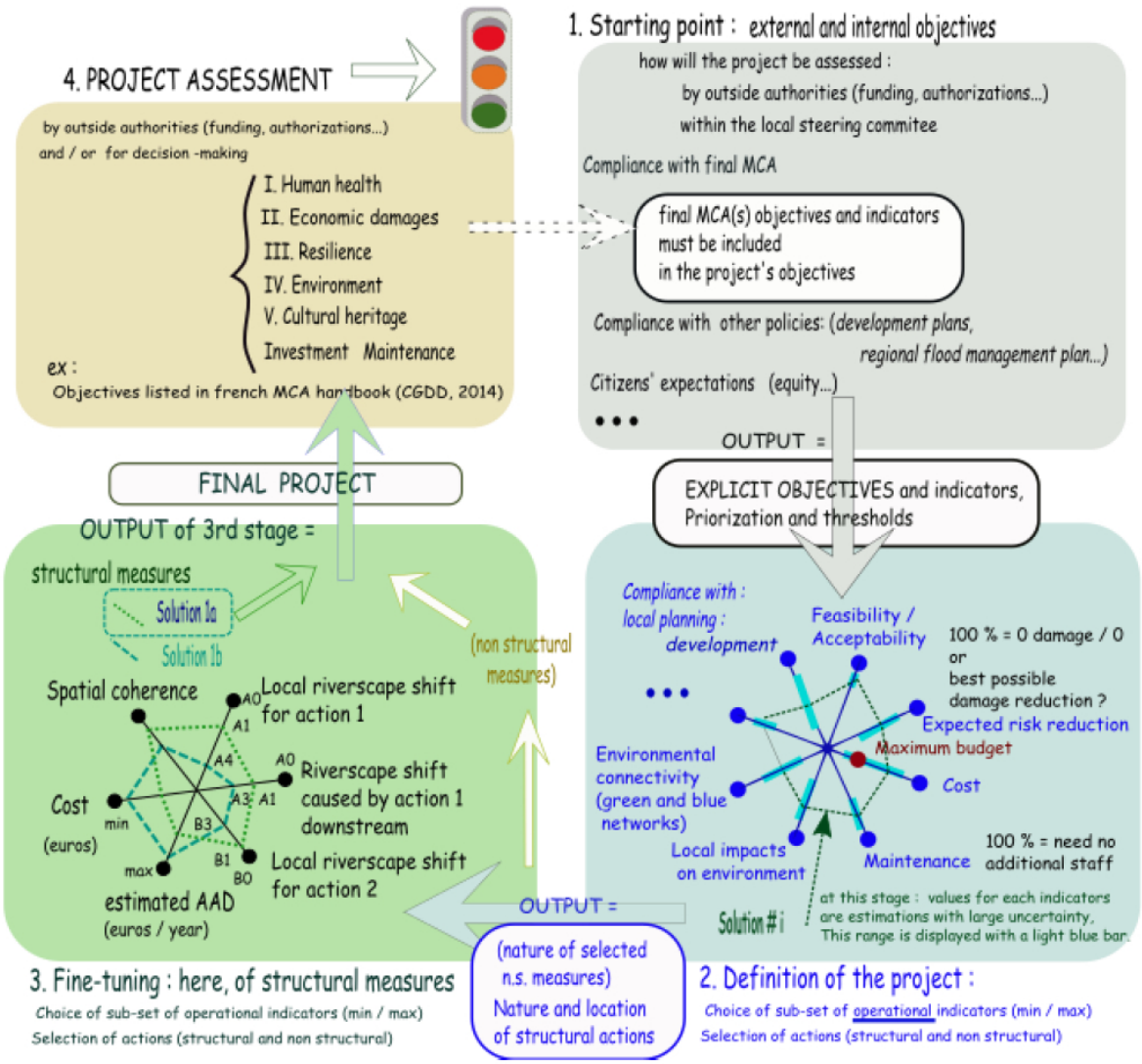


Table 3: Possible evolution of criteria displayed on radar graphs from early to final stages

Discussion

Although explicit objectives seem a prerequisite to any project, obtaining an exhaustive list of all the decision criteria that will be used might remain difficult. We also need an idea of the priorities, i.e. weights given to reach indicator,and thresholds (for a given criterion, can "poor" be tolerable if the other criteria are excellent, or not). Furthermore, there is no standard method to define synthetic "environmental indicators". In France, the national guidelines on MCA for flood risk mitigation projects list as "environmental indicators" only accidental pollutions of the environment caused by flooded facilities(CGDD, 2014). However, they announce on-going works, and "standard" environmental indicators should be given in a near future.Finally, to draft a project, we should not forget common-sense criteria like "feasibility" – including time-scale, acceptability, partnerships…- can also be very determining.

Another major difficulty is the assessment of indicators in early stages: only estimations can be reasonably provided. Table 3 suggests a "best situation" be defined, thus the score could be a percentage of this optimum. Similarly, the reliability of assessment is an interesting information: therefore, an expected score can be usefully completed by a range of uncertainty.

All these objectives remain theoretical and cannot be achieved if not supported by a transdisciplinary team, including in particular end-users from public and/or private organisms (Lafont, 2011; Lafont*et*

al., 2010; 2012; Tixier*et al,*. 2012; Vivien *et al.*, 2014). Practitioners who will be in charge of technical achievement or maintenance should also bring their expertise throughout the project: they can be aware of what is feasible and what is not, and of technical alternatives. Concerning public participation, we suggest it should take place in the early stages, and in particular in the definition of objectives to ensure public acceptance.

We insist on the necessity for the transdisciplinary team to follow and share the same conceptual and operational approaches, for example the riverscape typology, and thataslo includes guides for end-users (Lafont, 2011). Conceptual and operational phases are linked approaches, and have to be accepted and shared by the team. The triad [project/approaches/team] seems in our opinion a key to the success, because it constitutes the indispensable cement for the complete development of a given project. The triad differs from a project to another: other concepts, teams and end-users (Gaillard, 1997).

Conclusions

The idea is to make the best use of the competences of each involved person, including technical staffs.Co-conception implies the active participation of all. Therefore, our approach insists that first the objectiveshave to be explicit and shared, and that solutions must be found to discuss and compare the means of action, using common conceptual and operational views.

Our approach still has to be implemented for full-scale studies, in real and varied contexts,totest and improve the method to a fully operational stage. Only then can "guidelines' be written, but always allowing much freedom in the implementation. Future implementations should be followed closely, certainly not to control the process, but to capitalize on the experience. Social sciences should be closely associated to the project, to analyze the paths towards solutions: how different specialists collaborate, which were the expected and unexpected misunderstandings at the beginning, how they were identified and solved, how compromises were made, how each specialist around the table really influenced the final version of the project. Of course, each project is different, but feed-back analysis can always bring insight to the delicate art of project management and help identify obstacles and solutions for fruitful co-conception (Lafont 2011; Richard-Ferroudji, 2014).

Acknowledgements

This study started in collaboration between Irstea and Cracow University of Technology thanks to funding from PHC bilateral projects and EcoNet 3-partner projects.

References

Cavaillé, P., Dommanget, F., Daumergue, N.,Loucougaray, G.,Spiegelberger, T., Tabacchi, E., Evette, A., 2013. Biodiversity assessment following a naturality gradient of riverbank protection structures in French prealps rivers. Ecological Engineering, 53: 23-30.

CGDD, 2014. Analyse multicritères des projets de prévention des inondations - Guide méthodologique. RéférenceS. Ministère de d'Ecologie, du Développement Durable et de l'Energie: 86. (http://www.developpement-durable.gouv.fr/IMG/pdf/Ref_-_Guide_AMC_inondations.pdf)

Edjossan-Sossou, A. M., Deck, O., Al Heib, M., Verdel, T.,2014.A decision-support methodology for assessing the sustainability of natural risk management strategies in urban areas.Nat. HazardsEarthSyst. Sci. 14(12): 3207-3230.

Gaillard, J.M. 1997. Marketing et gestion de la Recherche et Développement. Collection Recherche en Gestion, Economica, Paris, 336 pp.

Junk W.J., Bayley P.B., Sparks R.E., 1989. The flood pulse concept in river-floodplain systems.Can. Spec. Publ. Fish.Aquat. Sci., 106, 110-127.

Koutecký, P., Prach, K., 2005.Recovery of alluvial meadows after an extreme summer flood: A case study. Ecohydrology and Hydrobiology 5(1): 33-39.

Lafont M, Jézéquel C., Vivier A., Breil P., Schmitt L., Bernoud, S., 2010. Refinement of biomonitoring of urban water courses by combining descriptive and ecohydrological approaches. Ecohydrol.Hydrobiol., 10: 3-11.

Lafont, M., Tixier, G., Marsalek, J., Jézéquel, C., Breil, P., Schmitt, L., 2012.From Research to Operational Biomonitoring of Freshwaters: A Suggested Conceptual Framework and Practical Solutions. Ecohydrol.Hydrobiol., 12 (1): 9-20.

Malard, F., Uehlinger, U., Zah R., Tockner, K., 2006. Flood-pulse and riverscape dynamics in a braided glacial river. Ecology, 87, 704-716.

Merritt, D.M., Nilsson, C. and Jansson, R,. 2010. Consequences of propagule dispersal and river fragmentation for riparian plant community diversity and turnover. EcologicalMonographs, 80:609-626.

Poulard, C., Lenar-Matyas, A., Łapuszek, M., Lafont, M., Schmitt, L., Jézéquel, C., Breil, P., 2011. Co-conception of integrated flood management solutions: riverscapes to facilitate dialog. Ecohydrology&Hydrobiology 11(1–2), 107-119.

Poulard, C., Breil, P., Lafont, M., 2013. Gérer les crues et les inondations, in:Chocat, B. (Ed), Ingénierie écologique appliquée aux milieux aquatiques ; pourquoi ? comment ? ASTEE, Paris, pp. 68-83.

Poulard C., Royet R., Ratomski J., Lenar-Matyas A., 2009.Dams with open outlets for flood control: some lessons to be learnt since 1905 *(in French*), Ingénieries EAT, Special Issue on Flood Prevention, 33-53.

Poulard, C., Lafont, M., Lenar-Matyas A., Łapuszek, M., 2010. Flood mitigation designs with respect to river ecosystem functions - a problem oriented conceptual approach. Ecol. Eng., 36(1), 69-77.

Richard-Ferroudji, A., 2014. Rare birds for fuzzy jobs: A new type of water professional at the watershed scale in France. Journal of Hydrology 519, Part C(0): 2468-2474.

Schmitt, L., Valette, L.,Valin, K.,Piegay, H. and Hallot, E., 2006. Proposition d'une méthode de typologie hydro-géomorphologique des cours d'eau et test sur un sous-bassin du Rhône (bassin de l'Yzeron).

Mosella, XXIX, 3-4, 2006, p. 323-340.

Schmitt L., Lafont M., Trémolières M., Jezequel C., Vivier A., Breil P., Namour P., Valin K., Valette L., 2011.Using hydro-geomorphological typologies in functional ecology: preliminary results in contrasted hydrosystems. Physics andChemistry of the Earth, 36, 539-548.

Tixier G., Rochfort Q, Grapentine L., Marsalek J., Lafont M., 2012. Spatial and seasonal toxicity in a stormwater management facility: Evidence obtained by adapting an integrated sediment quality assessment approach. Water Research, 46: 6671-6682.

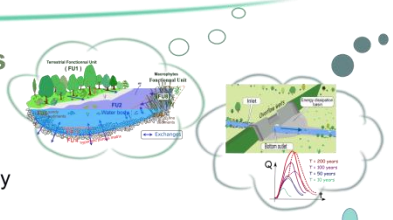
Vivien R., Tixier G., Lafont M., 2014. Use of oligochaete communities for assessing the quality of sediments in watercourses of the Geneva area (Switzerland) and Artois-Picardie basin (France): proposition of heavy metal toxicity thresholds. Ecohydrol.Hydrobiol., 14 (2): 142-151.

MAKING THE BEST USE OF ECOLOGICAL AND EFFICIENCY INDICATORS TO GUIDE FLOOD RISK PROJECT MANAGEMENT

Christine Poulard, Pascal Breil, André Evette (Irstea) ; Michel Lafont (Irstea / Les Jardins d'Artémis)
Laurent Schmitt (Université de Strasbourg, Image-Ville-Environnement) ; Régis Vivien (Ecotox Center) ; Mélanie Laluc (Burgeap)

1. IMPROVED RIVERSCAPE CONCEPT FOR DESIGN STAGES

Co-conception for integrated flood prevention projects



How can specialists with different objectives and different backgrounds achieve co-conception ?

- each specialist must explain his/her objectives and constaints in a synthetic way
- a common and shared objective must be defined

Defining synthetic supports for discussions

Natural and artificialised river elementary units

- For a given project and a given natural river, define elementary units with all possible modifications, with a description of the river functions and potential biodiversity. The consequences of modifications are explicitely described.

  This pragmatic typology is based on riverscapes (Malard, 2006), and was gradually developped to allow to take into account all relevant features.

  To ensure a global vision of the whole impacted domain, terrestrial units are defined when necessary, and the positive or negative interactions of neighboring elements are specified.

Physical Characteristics	semi-natural conditions **A1a**
Based on natural type (A0) + impervious lining ; (A1a= 30-50% & A1b: 50-70 %). Degraded type : A2 (100%)	
Surface Water / Ground Water connections decrease with imperviousness	
Biological Processes	
Metabolic processes diversity increases with SW/GW connections. The porous matrix fully acts as a filter (FU3, FU4). Type 1b with sandy or fine sediment deposits (FU5, FU6). Type 1a with macrophyte assemblages (FU8). Fewer processes on flat substrates (FU 7).	
Biodiversity and monitoring indices (here, French)	
diatom indices, oligochaete and vegetation Functional Traits, macrophyte indices, IOBS index and harmonization system. Traditional invertebrate indices and fish index can be used, but mainly in types close to a "natural" system (A1a). The use of geomorphological reference types (Schmitt et al. 2006; 2011) might be indispensable when physical restoration from a type 1 to type 0 (near natural or natural) is planned.	
Schematic cross-section (here, with Functional Units) *see fig 1.*	

Table 1: summarized description of a riverscape named "A1", based on Functional Units ; modified after Lafont (2011),

Measure the impacts of the project by the shifts in riverscapes

- The common objective is to meet civil engineering and hydrologic requirements with the lesser shifts in riverscape types.

Discussions towards concerted solutions

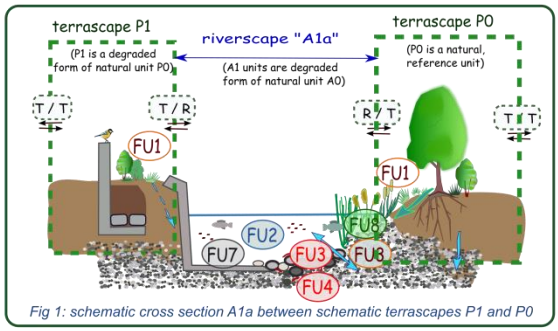


Fig 1: schematic cross section A1a between schematic terrascapes P1 and P0

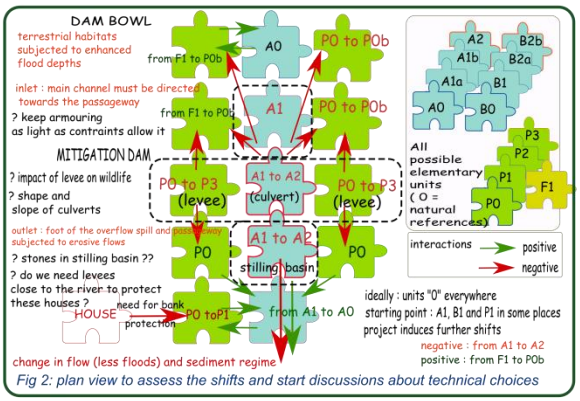


Fig 2: plan view to assess the shifts and start discussions about technical choices

Riverscapes must be tailor-made in concertation to help people understand each other. They will not offer solutions, but are meant to facilitate the discussions, so as to integrate suggestions from different specialists into a common solution. Each implementation will lead to a different description of units and of evolution indicators, depending on the natural context, the objectives of the project and the types of actions to be assessed.

Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture

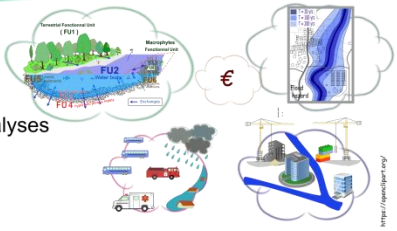
CONTACT :
Poulard Christine - christine.poulard@irstea.fr
Tél. +33 (0)4 72 20 87 92
Centre de Lyon-Villeurbanne - Hydrology-Hydraulics Research Unit
www.irstea.fr/lyon

MAKING THE BEST USE OF ECOLOGICAL AND EFFICIENCY INDICATORS TO GUIDE FLOOD RISK PROJECT MANAGEMENT

Christine Poulard, Pascal Breil, André Evette (Irstea) ; Michel Lafont (Irstea / Les Jardins d'Artémis)
Laurent Schmitt (Université de Strasbourg, Image-Ville-Environnement) ; Régis Vivien (Ecotox Center) ; Mélanie Laluc (Burgeap)

2. INDICATORS FOR DECISION MAKING AT DIFFERENT STAGES

Poster 1 focuses on the design stage, after the type of actions is already chosen (dry dams), and only variant of technical solutions are examined, within the same range of costs and efficiency. Poster 2 now considers co-conception throughout.
It presents a framework to guide decision-making at all stages, using Multi-Criteria Analyses



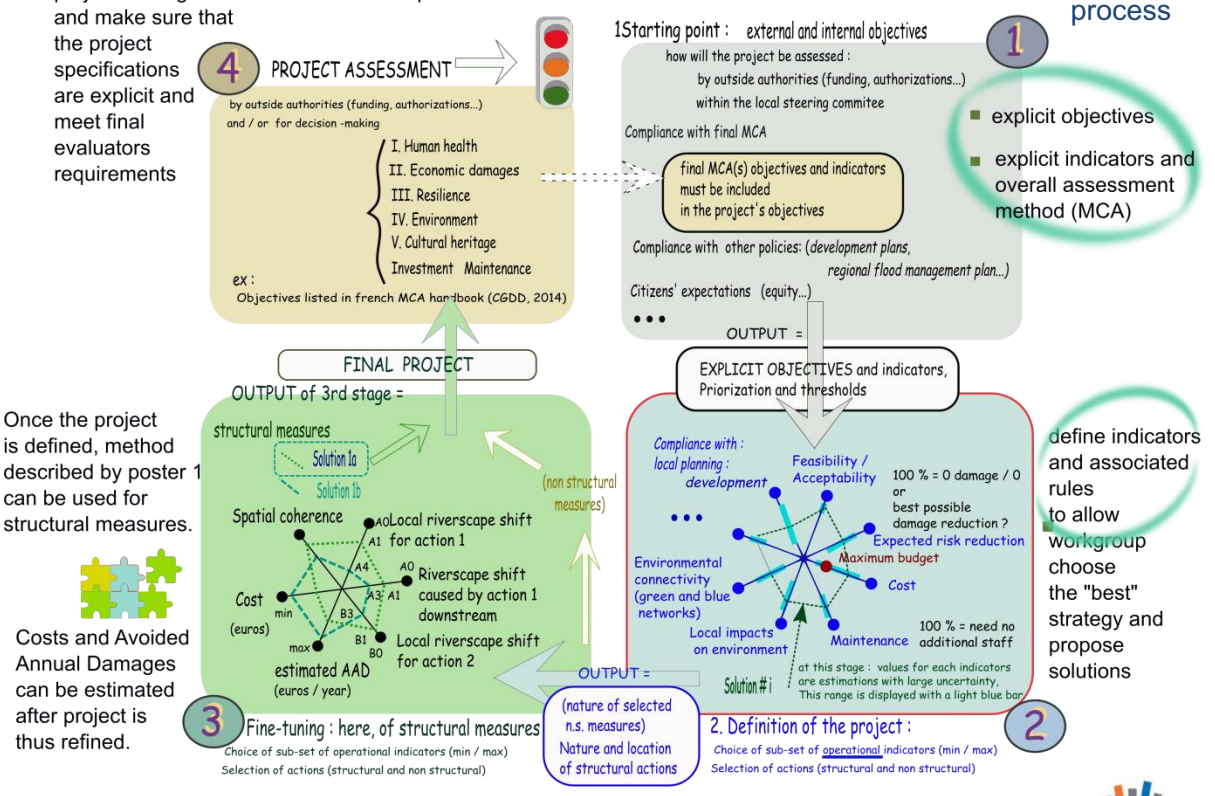
To make a good project : define what "good" means

Anticipate the final assessment

- The project will be evaluated by internal or external commissions for authorizations and funding ; project-manager should collect their requirements and make sure that the project specifications are explicit and meet final evaluators requirements

Define relevant indicators and rules at the appropriate level of occuracy throughout the process

- explicit objectives
- explicit indicators and overall assessment method (MCA)



Once the project is defined, method described by poster 1 can be used for structural measures.

Costs and Avoided Annual Damages can be estimated after project is thus refined.

define indicators and associated rules to allow workgroup choose the "best" strategy and propose solutions

Each projet will have its own description of indicators, depending on the context, the objectives of the project and the types of actions to be assessed.

Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture
CONTACT :
Poulard Christine - christine.poulard@irstea.fr
Tél. +33 (0)4 72 20 87 92
Centre de Lyon-Villeurbanne - Hydrology-Hydraulics Research Unit
www.irstea.fr/lyon

DOES THE BOCAGE OF BRITTANY (F) MITIGATE FLOODS ? FROM SCIENTIFIC CONTROVERSIES TO PUBLIC DEBATE

Christine Poulard[1], Guy Le Hénaff[2], Gilles Armani[2], Anne-Laure Achard[3], Laurent Grimault[4]

Irstea:[1]UR HHLY, [2] UR MALY, [3] IST-SGLY ; 5 rue de la Doua, CS 70077, 69626 Villeurbanne Cedex, France,*correspondingauthor*:christine.poulard@irstea.fr

[4]Creseb, Centre de Ressources et d'Expertise Scientifique sur l'Eau de Bretagne, 283 avenue du Général PATTON - CS 21101, 35711 RENNES Cedex 7 ; laurent.grimault@bretagne.bzh

Key words:Flood mitigation, hillslope, bocage, multiobjective strategy, concertation

Subtopics [1.1] [1.3]

Introduction

In a context of sustainable and integrated flood management, it is tempting to favor small actions in the hillslopes and non-structural measures over large hydraulic structures –which may have severe impact on the river ecosystems. However, according to the scientific literature, the effect on flood of actions in the hillslopes (land-use modification, small storage facilities…) is difficult to assess, and their efficiency on flood mitigation varies according to the physical context - which explains contradictory results in different studies. Yet, many authors agree that the mitigation effect dwindles with distance and flood severity.

This communication deals withthe gap between expectations and scientific results, focusing on the case of bocage, in Brittany, and discussesits causes and the ways to bridge it. Bocage is alandscapewhere agricultural plots are delineated by hedges. The expected role of hedges on floods is often invoked to protect and promote this threatened traditional landscape, and some people even claim that for flood mitigationhedges are preferable tostructures built in rivers[1]. So, the first question addressed here is how to write a synthesisfocusing on hedgerows, but also for whom it should be written,and through which medium. But it soon appeared that the main issue is to bridge the persisting gap between scientific and technical professionals on one side, and local inhabitants and associations on the other side.

Material and methods

The starting point was an extensive literature review on the effect of hillslope actions on floods, written for the French Ministry of Environment. Even with the use of on-line scientific databases, with tools which facilitate literature search, it was time-consuming to collect the relevantpapers: the huge variety of possible actions in the hillslopes means that many different keywords are used, and besides many very useful works are not focused exactly on the studied objects. For instance, we finally enlarged our search to the urban context, because methodological issues are similar (Poulard*et al.*, 2013).

Outside the scientific community, few institutions can afford expensive journals and access to scientific databases. This is why it appeared useful to share our work with practitioners, through syntheses. About bocage and floods in particular, excellent dissemination documents for

practitionersare already available in French (Mérot, 2003 and Mérot*in* CRESEB, 2014). Landscapes similar to bocage also exist in Great Britain, so synthetic documents about natural flood management in Englishmay also be of great interest (e.g. SEPA 2015a and b).

[1]localnewspaperOuest France: "Flood prevention : bocage, not concrete" (*Prévention des crues : du bocage, pas du béton*), 2014 jan 25; http://www.ouest-france.fr/prevention-des-crues-du-bocage-pas-du-beton-1884048 ;

« Against floods ? Plant real hedgerows » (*Contre les inondations ? Replanter de vraies haies*), 2014 jan 14, http://www.ouest-france.fr/contre-les-inondations-replanter-de-vraies-haies-1856266

So, to avoid redundancy and propose a complementary document, we chose to place bocage in a broader perspective and compare it with other actions, to make the best use of our literature review. We also chose to insist on the methodological issues, because the difficulty to quantify the effect of hillslope action is often underestimated. However, there is a persisting discrepancybetween the scientific consensus and public perception about bocage and flood, like about forests and floods (e.g. Calder, 2004). Indeed, many newspapers articles and internet pages convey explicitly or implicitly the idea that bocage plays a role in flood mitigation this idea. This opinion was defended, mainly by nature conservation associations, during two meetings recently organized, one by CRESEB about floods in Brittany (CRESEB, 2014) and a public regional conference about bocageorganized by the Council of the Finistère (ConseilDépartemental)[2].

Theory

Before writing a synthesis of their literature review on all actions in the hillslopes and an excerpt focusing on bocage. researchers of Irstea had to answer the following questions:

* **forwhom:**the syntheses address mainly the practitioners - project managers (local authorities), consultants, state services. They do not address directly the general public, but rather give elements to the local practitioners in contact with the public, like Creseb, whose mission is to facilitate exchanges between scientific and operational worlds.The language of the documents shall be French.

* **scope:** of course, practitioners would prefer practical tools, such as decision-trees to choose technical solutions and formulas for design. Consultants already know how to design one small dams or one storage area ; quantification of effect of other actions, involving a combination of delay, infiltration and many small storages in the landscape, is more difficult. Technical guides already exist in French for actions in rural hillslopes, but they mostly address local efficiency, and mainly against erosion (AREAS 2009, Ouvry 2012). However, our target here is the overall effect on floods of many actions at catchment scale ; no simple formulas can be expected. We chose instead to discuss methodological issues more generally. So, our syntheses will not be methodological guides, but will stay closer to bibliographical analyses. They must provide the readers with elements of knowledge and analyses. They must help engineers improve their design methodologies, and help project managers pilot these design studies.

* **content:** we have to find an acceptable compromise between concision and detail, but the existence of contradictory results - even in the scientific literature itself-and of real methodological difficulties for assessment of effect calls for a more detailed document, or at least of detailed appendices following an executive summary. We also decided to follow the same rules concerning references as in scientific

papers. In technical documents, it is often argued that the references thatcan notbe easily obtained should not be mentioned; instead, we chose to use many citations and give their references. Our point is that sourcing our statements gives weight to them, especiallyin the case of controversial or contradictory statements, and the reader must be able to further investigate some of the points if he wants to.

An extended bibliography is also necessary for a comprehensive and balanced synthesis. It also gives a good view of how science progresses: disagreement between papers is a bad surprise at first sight, but then the discrepancies are commented and analyzed. The reader also becomes aware of the methodological difficulties that he should also expect in his own projects, and what are the solutions proposed by scientists.

* through which medium: at the interface of science and practice, the documents could be published in scientific or technical journals, as reports, as internet pages, presented in conferences.The advantages and drawbacks for 4 such media are summed up in table 1: scientific and technical journals offer scientific validation, but impose strict requirements about size and content; internet pages offer more liberty in the content and updates. Internet pages can become really good media providing they are visible enough. Luckily, the media are not mutually exclusive, if done openly: atechnical paper could refer to website pages with a more detailed content – the remaining question being to inform practitioners about the existence of both documents. In a near future, professional social networks could be an answer to target practitioners, providing them with information they need.

	Report (PDF)	Internet page	Technical paper	Scientific paper
Nature and scope	Report on a topic given by sponsor	Website of the institute of the author(s) or partners, thematic websites (Creseb, WikHydro[3]…) *Scope:* dissemination, communication.	*Scope:* Share methods, results, concepts…	
			Methodological notes, projects descriptions, feed-back analyses…	high scientific quality and novelty are expected. Literature reviews are usually appreciated papers.
Allowed size	**Free ;**possibility to add technical appendices	**Free ;** possibility to have several levels of details through linked pages	a few pages (rarely more than 15 p) but possibility to have special issue.	a few pages, 6-15. Strict editor's requirements (structure of text…)
Reference list	No general rule (none or many references…)	No general rule ;possibility to add **extended reference list**with hyperlinks	Codified bibliographic rules. Reference list often limited (even down to 5 !)	Codified bibliographic rules. **Extensive**reference list demanded
Validation	Signature by authors, and sponsor of study if acting also as publisher.	Depending on the site:review process or not, possibility for readers to post comments or even suggest corrections ("Wiki")	**Peer-reviewing process**guarantees quality but slows the publication procedure. The journal's reputation and impact factor implicitly convey hints about the quality of the paper. For scientific papers, **number of citations** also hints about the interest and quality (after some time), but only among scientific community.	

[2]*Conférence départementale de l'environnement* 2014 ; http://www.finistere.fr/Le-Conseil-departemental-et-vous/Eau-Environnement/Toutes-les-actualites/Conference-departementale-de-l-environnement-Quel-avenir-pour-le-bocage-en-Finistere

[3] French portal hosted by the French ministry of Environment to favor knowledge exchanges between professional and stakeholders involved in water management ; http://wikhydro.developpement-durable.gouv.fr/index.php/Portail:Wikhydro

Targeted readership	Sponsor(s), their services and/or practitioners in general.	Informed readers, but **open to all**	Both scientific and technical communities	Mainly scientific community
Availability	With agreement of sponsor (on-line or upon request)	**Easy accessfor anyone**	Journals provide papers **on-line**, but subscription fees often limit the readership (especially for smaller structures). Development of "**open access**" should lift this restriction.	
Visibility	Authors' and sponsor's channels of diffusion. Edition within a series offers more visibility.	Dependson : hosting institution, ergonomics of the website, updates, attractiveness, richness of content, hyperlinks with other sites…	Visibility depends on editors and their open access policy. For referenced journals, **scientific databases** offer excellent visibility to the papers, enhanced byefficient search tools.	
Update	Addendum or a version superseding the previous one.	**Complements and corrections can be published quickly**	If new developments, a new paper has to be published: it will not "replace" the previous one, it must stand alone and be innovative enough.	

Table 1: compared characteristics of 4 publication media (advantages are highlighted in bold)

Results

One striking feature, especially at the beginning of the process, was the existence of contradictory results about the efficiency of hillslope actions for flood mitigations. Understanding the reasons why discordant conclusions were published was in fact the most interesting part of the review process. The main explanations to these differences are:

differentissues in studies (erosion, pollutant transfer, moderate floods or extreme floods, at local or catchment scale…). Generalizing often leads to erroneous conclusions: a successful erosion control does not imply necessarily mitigation of floods, and even less of large floods;

the behavior of actions in the hillslopes strongly varies in different contexts (slopes, soils, spatial pattern of natural and man-made features) ;

assessing the effect of many small actions at the scale of a catchment and over the flood regimeis difficult, either from measurement or from models.

This literature review contributed to enrich other studies and communications, and several documents in French were already derived from this review, addressing each a specific point, including:

- a conference paper on the comparison of decentralized flood hazard mitigation in urban and rural contexts (Poulardet al. 2013), showing similar means of actions and methodological difficulties,

- a communication in a Creseb meetingaboutflood hazard reduction strategies, insisting that all objectivesmust be listed and that the hydrological effects must be studied at the scale of the flood regime and of the catchment. Cresebintegrated it in a synthetic account of the day (Creseb, 2015); a paper in a generalist technical journal: from the many definitions of runoff towards better diagnosis and action (Poulardet al. 2015).
- lastly, a specific literature review was carried out on bocage and floods. Bocage appears complex to describe in terms of runoff control.Figure 1 illustrates interactions between runoff and banks:depending on their orientation, banks will slow the runoff (1, 3) or not (7). Slowing water behind banks facilitatesinfiltration, especially in cultivated fields where the soil is compacted elsewhere (Figure 2).However,since banks collect and concentrate flows, erosion can occur after

the end of a bank (red arrows). As it was very well explained at the Quimper conference[4], bocage is a whole landscape, with agricultural plots and sometimes wetlands. The effect at the scale of the whole catchmentdepends on each feature and their connections : hillslopes, differently oriented embankments, ditches, wet meadows and rivers (Viel*et al.*, 2014). Since bocage landscapes are not originally designed for flood mitigation, thisspatial pattern has no reason to be optimal for this effect. However, restauration projects could offer opportunities to enhance alleviation effects. Solutions must be sought at the scale of the system: improve the pattern of banks to slow and control runoff, and connect it to flood expansion areas when available. Wet meadows situated in flatter areas and close to the river can play this role (8), if temporary flooding is acceptable and safe – the water level should not be allowed to rise too high behind a normal bank, for fear of breaching.

- finally, the difficulties of assessing the efficiency of a strategy to mitigate floods (either by dams or actions in hillslopes) are discussed. The effects must be studied over the flood regime, not on one "design flood". The literature review leads to conclude that effects of actions in the hillslopes can be significant on small events, butdwindle for long or intense rainfall (e.g. Salazar 2012). Furthermore, studying dispersed small features is a complex task, whether through measurements or modelling. Studying concentrated flow is easier, but in bocage the runoff can alternatively be concentrated by a bank and spread over a slope again. Besides, erosion and deposit can change significantly flow paths, even during a rainfall event !

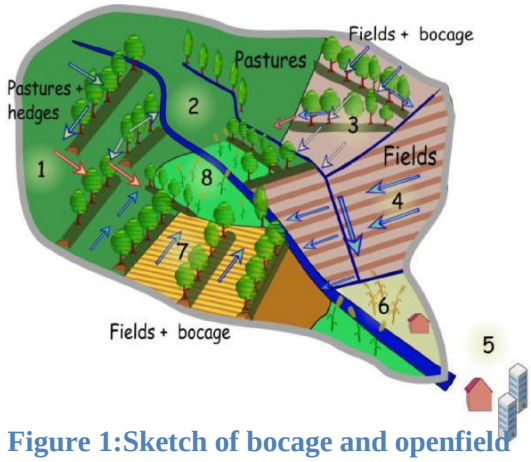


Figure 1:Sketch of bocage and openfield features

Figure 2: holistic vs sectorial view of a tree-planted bank

- A 7-page document summarizing this state-of-the-art of knowledge about bocage was drafted after the conference on bocage in Quimper (Poulard and Le Hénaff, 2015), including references to the conference presentations and discussions, and followed by a more technical appendix. Its objectives are:
- to warn against generalization (slowing the runoff limits erosion, but mitigates only small floods) to point out the gap between scientific results and local perception, and propose explanations to it to help converge towards a balanced analysis. Exaggerating the action of bocage on floods is
- un-necessary, because its roles on biodiversity, erosion or heritage already justify preservation actions. In parallel, the drawbacks of flood mitigation structures must indeed be mentioned in
- flood prevention projects: side-effects on the ecosystems and sediment transport, low reversibility, efficiency only up to a given flood intensity, and even probability of failure.
- To advocate for the definition of future flood mitigation strategies in concertation, at the proper scale. "Experimental" solutions can be tested, provided their actual effects are assessed,

meaning field measurement and subsequent analysis -experimental implementations (Stokes *et al.*, 2014).

[4] http://www.finistere.fr/content/download/92112/741212/file/2014_CDE_9_Agrocampus-Montembault.pdf

Discussion

We started from a literature review made in Irstea on the effect of hillslope actions on floods, from the scientific community towards the practitioners. We assumed that studying and analyzing many scientific works would identify the reasons for controversies, and lead to consolidated conclusions. The aims were to describe the state-of-art and provide objective elements useful to decision-makers, to help them make informed decisions for their flood prevention strategies, and useful for engineers in charge of drafting the projects. However, the synthetic note on bocage and floods raised the problem of further acceptance by a larger audience, in a context where public participation is developing. In Brittany, bocage is assumed to have a significant effect on floods, and thereforethe validity of scientific works-on which our syntheses are based- is questioned. Whether papers are peer-reviewed and whether journals are top-ranking or not are weak arguments in a local context, where they contradict people's own experience - and expectations. Reports are also suspected to be partial, favoring structural measures for bad reasons, and ignoring biodiversity issues.Another difficulty is that studies from other regions can be dismissed as irrelevant to the local context. So, with this background of controversies over research results, knowledge can not be transferred by syntheses documents in one shot, in a "top-down" approach.

Interfaces linking researchers and practitioners, like CRESEB, are needed to overcome the deadlock.Regional and local structures know well the physical and social context, and can build relationship over time with people. As regional facilitators of exchanges[5],Creseb collects and help share the different points of view. For instance, local residents observe that hedges planted on earth banks do strongly impact hillslope runoff trickling during rainfall events. When scientists write that hedgerows have little impact on floods, it is interpreted as a total ignorance of field reality. In fact, processes appear intuitively simple but are in fact much more complex, especially at the scale of the catchment and at the scale of the flood regime. It takes skills to explain this to non-specialists, keeping enough technical quality without sounding dry or obscure. For instance, presenting bocage as a succession of storage and retarding structures is a good way to illustrate flood transfer issues, but this schematic description may be resented as simplistic, almost offending, because it ignores all other aspects.Being in contact with scientists of all involved disciplines, the approach ofCreseb isholistic (Figure 2): runoff is only one of the aspects, and disappointing conclusions on floods can be more easily accepted if balanced by other positive conclusion.At a local scale, Local Water Committees in charge of implementing locally French national water policies (in particular in accordance with the European Water Framework Directive) also allow stakeholders to meet each other and exchange points of view, and identifyconcerted actions for integrated water management. Knowledge and questions must be collected from all, analyzed in a balanced way, and disagreements or misunderstandings must be debated.Regional and local structures can organize public meetings, as well as more specific interviews on a given topic, to better characterize for instance local residents' points of view and local specificities. They also help bring local actors' knowledge and expectations to the attention of researchers, when they define their research questions and throughout their research process. Keeping in touch with the local context is a prerequisite for applied research to be really useful, in particular in water management, involving many actors and objectives.

[5]CollègeCoopératifen Bretagne, report on the role and modalities of action of Creseb (in French),http://www.creseb.fr/index.php?option=com_content&view=article&id=494:synthese-de-letude-conduite-par-le-ccb&catid=127:des-outils-et-references-interessantes&Itemid=200088

With time, through debates and interactions, the aim is to achieve a co-construction of a common corpus of knowledge, and also to identify questions for further research.Indeed, local studies, including field experiments, remain invaluable to gain and consolidate knowledge, but also to root this knowledge into the local heritage (Stokes, 2014 ; SEPA 2015).

Conclusions

The present work showed complementarity between research institutes and regional networks, here mainly Irstea and Creseb. In a context with complex processes, controversy and diverging objectives, technical transfer is useful but must be integrated in a regional, long-term, multi-actor process towards consolidation and acceptability. It is important to keep track of the whole process, so as to show progress and not fall more than once in the same pits.

Mutual incomprehension oftenarisesfrom major differences in objectives. Flood hazard is by nature a random process: floods may appear to many people as a remote issue, overshadowed by other more concrete, visible and urgent problems. This is why the responsibility of flood prevention is often a thankless task, appearing to interfere with economic activity or environmental issues. So, it is both a difficulty and a challenge to define a flood management strategy in agreement with the other national and regional policies (water quality, development…) and in concertation withall stakeholders in the catchment.Every stakeholder has his own objective(s) ; prior to any concertation, they should become aware of and respect the objectives of all the others: nature conservation, agriculture, sustainability, landscape, water quality, flood prevention… Surprisingly, people exposed to floodhazard might not be the more active in the debates, because for them this hazard may be only a remote possibility among many other concerns ; in contrast, environmental groups and inhabitants of the upper catchment where hydraulic structures are projected are likely to oppose more strongly structural measures, because for them these structures are concrete and immediate problems. Of course, after major floods, this pattern is bound to change drastically ; local authorities have the responsibility to keep the debates balanced between all objectives, and to ensure relevance and sustainability of solutions.

Acknowledgements

Ourscientific literature review about hillslope actions and floods was funded by the French Ministry of Environment (BRM). The recent conferences organized by CRESEB and ConseilDépartemental of Finistère provided excellent invited talks of several disciplines,and allowed discussions open to different points of view.

References

AREAS,2009. Aménagementsd'hydrauliquerapprochée, Technical training (in French), 161 slides. Retrieved from http://www.areas.asso.fr/images/formations2009/amgtsHD.pdf

Calder, I. R., 2004. Forests and water - Closing the gap between public and science perceptions.WaterScience and Technology. 49: 39-53.

CRESEB(2015 June 16). Inondations en Bretagne: contrôle de l'aléa et culture du risque. Detailed account of the 2014/05/26 thematic Day for Flood Risk Management in Britany (synthesis of all the participants' slides and discussions, in French). Retrieved from http://www.creseb.fr/index.php?option=com_content&view=category&layout=blog&id=137&Itemid=200098

Mérot P., 2003. Le comportement des petits bassins versants ruraux dans le contexte des crues et des inondations, La Houille Blanche, (6): 74-82.

Ouvry J.F., Richet J.B. et al., 2012. Fascines & haies pour réduire les effets du ruissellement érosif -Caractérisation de l'efficacité et conditions d'utilisation, AREAS, 70 p. http://www.areas.asso.fr/images/expe%20autres/efficacite_haies_fascines_AREAS_68p.pdf

Poulard, C., Berthier, E., Breil, P., Labbas, M., Henine, H., Hauchard, E., Radzicki, K., 2013. La gestion des eaux pluviales coule de source, de l'amont à l'aval, du rural à l'urbain et vice-versa. 8e conférence internationale Novatech, Stratégies et solution pour une gestion durable de l'eau dans la ville, 27/06/2013 -, Lyon (F), 10 p.

Poulard, C., Breil, P., Hauchard, E., Dehotin, J. Lagadec, L.R., Patrice, P., 2015. Le ruissellement: le comprendre pour diagnostiquer et agir. Techni.Cités.Mars 2015, pp 21-28

Poulard, C., Le Hénaff, G., 2015. Compte-rendu thématique sur lesliens entre bocage, ruissellement et inondations. Document de travail: éléments de réflexions –Janvier 2015. Available at http://www.finistere.fr/content/download/95559/768415/file/CR-Irstea-ConferenceBocageQuimper2014-CG29-v02.pdf

SEPA (2015 June 16)a.Natural Flood Management Position Statement ; The role of SEPA in natural flood management. 10 p. Retrieved from http://www.sepa.org.uk/media/42133/sepa-04-12-position_statement_the_role_of_sepa_in_natural_flood_management.pdf

SEPA(2015 June 16)b.Identifying Opportunities for Natural Flood Management, December 2013, 13 p. Retrieved from http://www.sepa.org.uk/media/33480/natural_flood_management_2013.pdf

Salazar, S. *et al.*, 2012.A comparative analysis of the effectiveness of flood management measures based on the concept of "retaining water in the landscape" in different European hydro-climatic regions.NHESS. 12(11): 3287-3306.http://www.nat-hazards-earth-syst-sci.net/12/3287/2012/nhess-12-3287-2012.pdf

Stokes, A. et al., 2014. Ecological mitigation of hillslope instability: Ten key issues facing researchers and practitioners. Plant and Soil 377(1-2): 1-23.

Viel, V., Delahaye, D. and Reulie, R.,2014. Impact de l'organisation des structures paysagères sur les dynamiques de ruissellement de surface en domaine bocager. Etude comparée de 3 petits bassins versants bas-normands, . Géomorphologie: relief, processus, environnement 2014.

SOIL WATER CONSERVATION AND DEEP PERCOLATION IN MEDITERRANEAN SHRUBLANDS IN A CLIMATIC GRADIENT OF SOUTHEAST SPAIN

Ruiz-Yanetti, S.[1,5], Manrique-Alba, A.[1, 2], Moutahir, H.[1, 2], Chirino, E.[3, 4], Lledó, M.J [1], Maturano A.[2] , Bellot, **J.**[1,2]

[1] Department of Ecology, University of Alicante, Apdo. 99, 03080 Alicante, Spain
[2] Institute "Ramon Margalef", University of Alicante, Apdo. 99, 03080 Alicante, Spain
[3] School of Engineer Forestry, Polytechnic Higher School of Chimborazo. Panamericana Sur km. 1½, Riobamba, Ecuador
[4]Joint Research Unit University of Alicante-Foundation CEAM, University of Alicante, Apdo. 99, 03080 Alicante, Spain
[5] Department of Ecology, Universidad de los Andes, 05101 Mérida, Venezuela.
*samanthayanetti@hotmail.com

Key words (ecohydrology, dryland, soil moisture, groundwater recharge)

In southeast Spain groundwater is the main source for domestic and agricultural water supplies. In this region, it is expected that changes in temperature and rainfall will alter the vegetation cover and deep percolation (groundwater recharge). An accurate knowledge, about how the soil hydrological response is influenced by climate and vegetation cover, is important for sustainable water resources planning and effective water use. Considering that shrubland is one of the most characteristic vegetation cover in this region, our aims were; (1) To determine the soil water content in Mediterranean shrublands in three experimental sites along a climatic gradient (dry to semiarid) and (2) To assess the influence of each shrubland on groundwater recharge to aquifer in the experimental sites.

Materials and methods

To achieve these aims, three shrublands communities on calcareous soil (recharge area) were selected along a dry to semiarid gradient (610 to 300 mm of mean annual rainfall) in Alicante province. Mela site (38º42'02"N; 0º16'37"W) is in the dry area and two sites in the semiarid area Cabeçó d'Or (38º30'28"N; 0º24'04"W) and Ventós (38º28'43"N; 0º36'19"W). In each site, three plots (100 m^2) were selected and soil properties and vegetation characteristics (species and cover) were determined; vegetation cover of each shrublands was 90% (Mela), 82% (Cabeçó d'Or) and 40% (Ventós). For this study, microclimate data and soil moisture condition of two contrasted hydrological years (2012/13 as wet year and 2013/14 as dry year) were monitored. An automatic weather station in each field site was installed, which monitored the continuous records of rainfall (mm), air temperature (ºC), relative air humidity (%) and global radiation ($W.m^{-2}$). In order to determine the soil water content, soil moisture (%) was monitored on bare soil (inter - patches) and under shrubland. We used two experimental design and methods: (1) Monthly measures, in each plot (% w/w; from 0 to 15 cm, soil depth) using the Time Domain Reflectometer Method (TDR100, Campbell scientific, Inc. Logan, Utah, USA), by means of six TDR probes per plot, on bare soil inter-patches and under shrubland and (2) Hourly measures, in each site (% w/w; from 10 to 20 cm, soil depth) by continuous recording of four soil moisture sensors per site (10HS Decagon devices, Inc. Pullman, WA, USA), on bare soil inter-patches

and under shrubland. With the aim of assessing the influence of each shrubland on groundwater recharge, we estimated the main soil water flows (interception, evapotranspiration and deep percolation or recharge to aquifer) using HYDROBAL eco-hydrological model (daily resolution). For model validation, we compared the observed daily soil moisture vs. estimated soil moisture.

Main results

Along the gradient, in the wet year the annual rainfall was the twice of the mean annual rainfall of each site while during the dry year it rained an amount equal to a half of the average. Our results showed significant differences ($p<0.05$) between the soil moisture on bare soil inter-patches and under shrubland, both in wet and dry periods; being the soil moisture under each shrubland lower than on bare soil inter- patches (Fig. 1). HYDROBAL gave good estimations of the main soil water flows. The validation process showed good fits and all correlations between observed and estimated soil moisture were strong and significant (R^2=0.86, 0.90 and 0.87 in Mela, Cabeçó d´Or and Ventós sites, respectively, $p<0.001$). Both in the wet year and in the dry year, the interception by shrubland and evapotranspiration, which is the main outflow, were higher in the dry site due to the high cover (Fig. 2). In the wet year, the deep percolation in Mela site was 32% of annual rainfall (287.25 $L.m^{-2}$) while in Cabeçó d´Or and Ventós it was 29 % (115.32 $L.m^{-2}$) and 40% (178.96 $L.m^{-2}$), respectively. Although, in Mela the value of deep percolation in terms of $L.m^{-2}$ was the highest due to the high total rainfall in this site (Fig. 2). During the dry year the deep percolation decreased considerably in each site due to decreases of the rainfall, being from dry to semiarid 24.57, 6.15 and 2.26 $L.m^{-2}$, respectively (Fig. 2).

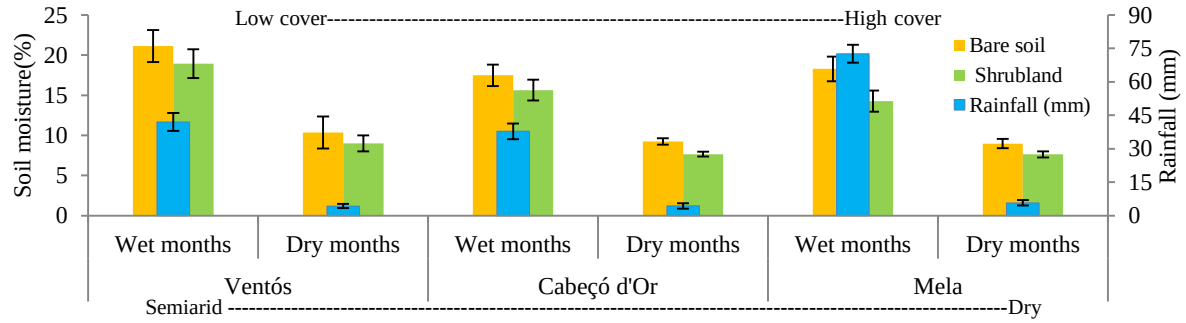


Fig.1. Soil moisture (%) on bare soil inter-patches and under shrubland, during wet months and dry months.

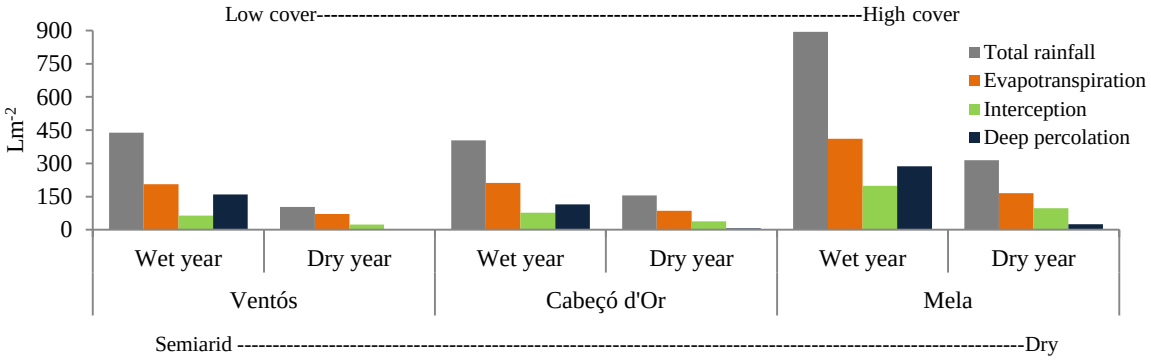


Fig.2. Soil water flows estimated with HYDROBAL model for each field site over two contrasted hydrological years (2012/13 as wet year and 2013/14 as dry year).

Conclusion

Soil water content showed different results due to the role of shrublands cover and total rainfall. The soil moisture indicated differences between the processes of evaporation (in bare soil inter-patches) and evapotranspiration (under shrubland). The deep percolation behaves differently in dry years and in wet years. In the wet year, the percentage of groundwater recharge increases with a low cover. In the dry year, the groundwater recharge in each site was highly affected by the decrease of the total annual rainfall, being higher in the dry site where rained the twice than in semiarid sites. This should be considering for the groundwater resource management during dry periods.

Aknowledgements

This work is supported by the Spanish Ministry of Economy and Competitiveness trough the project ECOBAL (CGL2011-30531-C02-01).

Soil water conservation and deep percolation on Mediterranean shrublands in a climatic gradient of Southeast Spain

Ruiz-Yanetti, S[1,3] ., Manrique-Alba, A.[1,2], Moutahir, H.[1,2], Chirino, E. [4], Lledó, M.J.[1,2], Maturano A. [1,2], Bellot, J.[1,2]

[1]Department of Ecology and [2]IMEM "Ramon Margalef", University of Alicante.
[3]Department of Ecology, Universidad de los Andes, 05101 Mérida, Venezuela.
[4]Faculty of natural resources, Polytechnic Higher School of Chimborazo, Riobamba, Ecuador.

* samanthayanetti@hotmail.com

1- INTRODUCTION

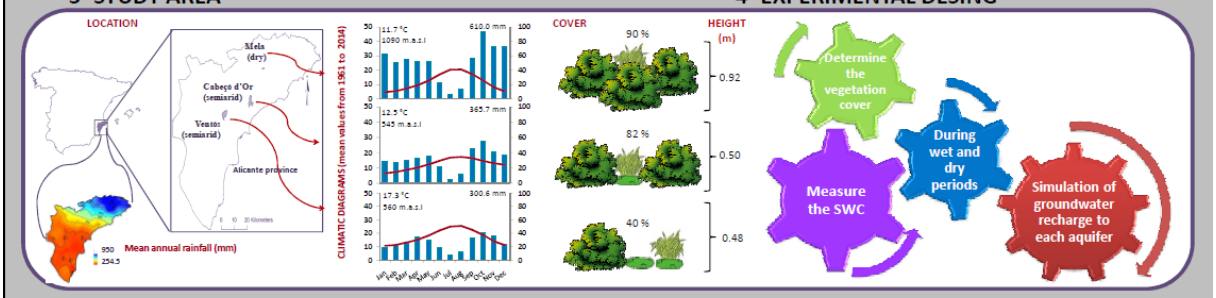
In Southeast Spain groundwater is the main source for domestic and agricultural water supplies. In this region, it is expected that changes in temperature and rainfall will alter the vegetation cover and deep percolation (groundwater recharge to aquifer).
An accurate knowledge about how the soil water content is influenced by climate and vegetation cover, is important for sustainable water resources planning and effective water use.

2- OBJECTIVES

Considering that shrubland is a characteristic vegetation cover in this region, our aims were:

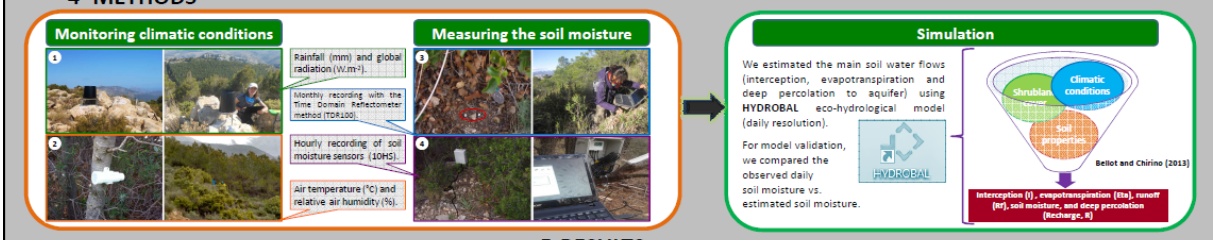
1. To determine the soil water content (SWC) in three Mediterranean shrublands from dry to semiarid.
2. To assess the influence of each shrubland, along the climatic gradient, on groundwater recharge to aquifer.

3- STUDY AREA



4- EXPERIMENTAL DESING

4- METHODS



5-RESULTS

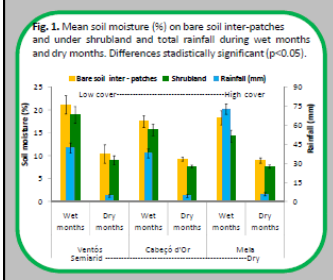


Fig. 1. Mean soil moisture (%) on bare soil inter-patches and under shrubland and total rainfall during wet months and dry months. Differences stadistically significant ($p<0.05$).

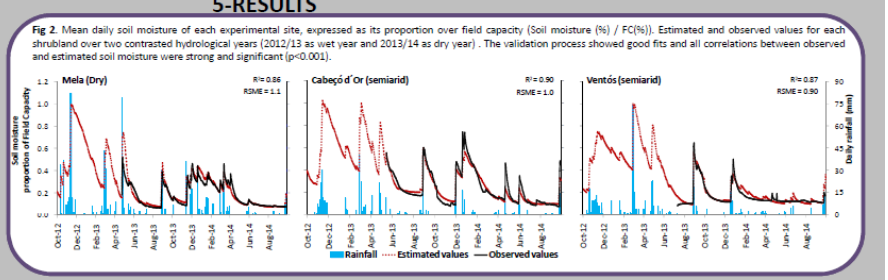


Fig 2. Mean daily soil moisture of each experimental site, expressed as its proportion over field capacity (Soil moisture (%) / FC(%)). Estimated and observed values for each shrubland over two contrasted hydrological years (2012/13 as wet year and 2013/14 as dry year) . The validation process showed good fits and all correlations between observed and estimated soil moisture were strong and significant ($p<0.001$).

WET YEAR

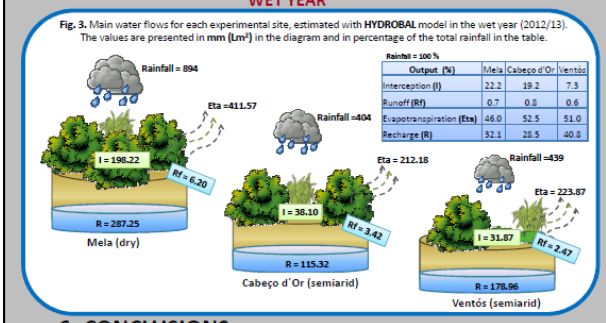


Fig. 3. Main water flows for each experimental site, estimated with **HYDROBAL** model in the wet year (2012/13). The values are presented in **mm (Lm²)** in the diagram and in percentage of the total rainfall in the table.

Rainfall = 100 %

Output (%)	Mela	Cabeço d'Or	Ventós
Interception (I)	22.2	19.2	7.3
Runoff (Rf)	0.7	0.8	0.6
Evapotranspiration (Eta)	46.0	52.5	51.0
Recharge (R)	32.1	28.5	40.8

DRY YEAR

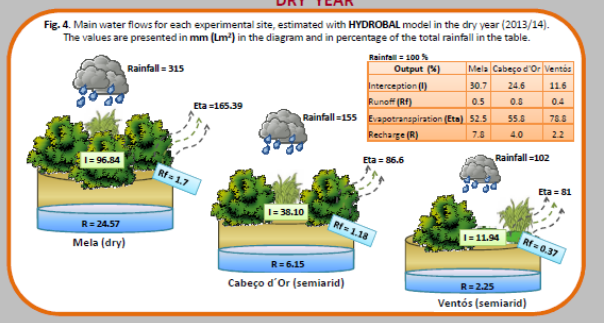


Fig. 4. Main water flows for each experimental site, estimated with **HYDROBAL** model in the dry year (2013/14). The values are presented in **mm (Lm²)** in the diagram and in percentage of the total rainfall in the table.

Rainfall = 100 %

Output (%)	Mela	Cabeço d'Or	Ventós
Interception (I)	30.7	24.6	11.6
Runoff (Rf)	0.5	0.8	0.4
Evapotranspiration (Eta)	52.5	55.8	76.8
Recharge (R)	7.8	4.0	2.2

6- CONCLUSIONS

❖ The soil moisture indicated differences between the processes of evaporation (in bare soil inter-patches) and evapotranspiration (under shrubland).

❖ The deep percolation behaves differently in dry and wet years. In the wet year, the percentage of groundwater recharge increases with a low cover. In the dry year, the groundwater recharge in each site was highly affected by the decrease of the annual rainfall. This should be considering for the groundwater resource management during dry periods.

ACKNOWLEDGEMENT

This work is supported by the Spanish Ministry of Economy and Competitiveness trough the project ECOBAL (CGL2011-30531-C02-01).

POTENTIAL IMPACTS OF CLIMATE CHANGE ON HYDROLOGY OF WESTERN SIBERIAN LOWLAND CATCHMENTS

Rajesh Sada, University of Kiel, rajesh_sada@hotmail.com

Dr. Britta Schmalz, University of Kiel, bschmalz@hydrology.uni-kiel.de
Prof. Dr. Nicola Fohrer, University of Kiel, nfohrer@hydrology.uni-kiel.de

(Climate Change, Statistical downscaling, Hydrology, Western Siberia)

Topic of this work

The domain of this research is the impact of climate change on hydrological components. This study analyzes the possible future climatic changes in Western Siberian lowland catchments and resulting changes in hydrological regimes thereto. The study was focused in three catchments viz., Pyshma, Vagai and Loktinka, which are located in southern part of Western Siberia lowland region.

Research question

This study is primarily guided by following two research questions:
How will be the future precipitation and temperature regime in the selected catchments?
How will these changes in climatic condition affect the hydrological components in that area?

Originality of this work

Western Siberia is a globally important area in terms of its food production and carbon sequestration. The region is currently facing large scale land use changeand also change in climatic variables. The change in temperature of Siberia is highest among the entire northern hemisphere and similarly the change in precipitation is spatially and temporally different.There are limited strategies in the study area to adapt to the situation and mitigate the problem which certainly will have implication on the socio-economy of the area, making this region highly vulnerable to the change in climate. Hence, there is a need to increase information for people in dealing with the uncertainties and risks which certainly requires forecasting tools and scenarios. Though there are several studies on climate change and hydrological impacts, they only cover large spatial scale and unfortunately, there is not even a single study which used climate and hydrological modelstoforecast future hydrological regimes in the selected three study catchments. It is in these regards, this study is extremely valuable and important. The SASCHA (Sustainable Land Management and Adaptation Strategies to Climate Change for the Western Siberian grain belt) project underway at University of Kiel, Germany, aims to fill this research gap and this study is a part of this attempt.

Data and / or method

This study basically involved four steps. These steps are (1) acquire and use general circulation models (GCMs) to project future global climate scenarios, (2) establish statistical relationship between GCM data and observed data, (3) downscale the GCM output based on the established statistical relationship, and (4) use of ecohydrological model Soil and Water Assessment Tool (SWAT) to simulate the effects of climate change on hydrological regimes.

The hydro-meteorological data required for the study were collected and compiledbythe SASCHA project. The Statistical Downscaling Model 4.2.1 (SDSM) was used to downscale and project the future climate data and the ecohydrological model SWAT was used for analyzing the impacts on hydrological components. The study used CMIP5 climate model i.e., Canadian Earth System Model (CanESM2) and NCEP/NCAR reanalysis project data as large scale atmospheric variables and wasdownloaded from Canadian Climate Data and Scenarios webpage. The downscaling was done for three different scenarios used in recent IPCC fifth assessment report viz., Representative Concentration Pathway (RCP) 2.6, 4.6 and 8.5.

Main results

The statistical downscaling showed that there will be an increase in both minimum and maximum temperature at all the stations under all RCPs. The study revealed that the increase in mean annual maximum temperature will range from 8^{o}C to 10^{o}C in the 2080s under RCP 8.5 scenario withhighest increase projected forKamyshlov and Ekaterinburg stations. Similarly, the increase in mean annual minimum temperature will range from 8.8^{o}C to 10^{o}C in 2080s under the same scenario. By the end of the 21st century, the lowest increase will bein Ishim, the easternmostamong the five stations i.e., 3^{o}C and 3.7^{o}C for maximum and minimum temperature respectively under RCP 2.6 scenario.

The mean annual daily precipitation will also increase at all the stations and under all the scenarios. The highest (0.93 mm/day) and lowest (0.2 mm/day) increase will be in Ekaterinburg under RCP 8.5 and Kamyshlov station under RCP 4.5 respectively. The annual streamflow also tends to increase at all the catchments under all the scenarios. Unlike temperature and precipitation, the highest increase in streamflow will be under RCP 2.6. While the highest increase in mean annual streamflow of Pyshma catchment will beupto 112 m^3/s in 2080s, it will be 14.4 m^3/s and 2.5 m^3/s in Vagai and Loktinka catchment respectively. The highest increase will be seen in cold seasons in all the basins under all scenarios.

Discussion

It is clearly seen from this study that the southern part of Western Siberian lowland catchments are going to be warmer in coming days due to which the snowfall will be decreased even though the precipitation is going to increase. This has implication on streamflows showing considerable increase in winter river discharges. This result also indicates that the climate of this region will affectfuture agricultural cultivation as the growing degree days will increase and the water availability changes. However, this study should be followed by the larger study which incorporates multiple CMIP5 models and studies on landuse / land cover change so that the changes in hydrological regimes can be more appropriately examined.

Acknowledgement

This study was conducted as part of project SASCHA (‘Sustainable land management and adaptation strategies to climate change for the Western Siberian grain-belt’)which isfunded by the German Government, Federal Ministry of Education and Research within their Sustainable Land Management funding framework (funding reference 01LL0906C).

MANAGING ECO-HYDROLOGICAL PROCESSES IN THE JOINT APPLICATION OF THE WATER FRAMEWORK AND FLOOD DIRECTIVES: PRINCIPLES AND BEST PRACTICE ON THE RHONE MEDITERRANEAN RIVER BASINS

Benoit Terrier

benoit.terrier@eaurmc.fr
Agence de l'eau Rhône Méditerranée Corse
Direction de la planification et de la programmation Hydromorphologie des eaux de surface et incidences écologiques 2,4 allée de Lodz F-69363 Lyon cedex 07 - France

River basin managers have a challenge in designing and implementing integrated solutions to restore or preserve the river ecology while at the same time ensuring the required standards of flood protection. In that respect, the Water framework and the Flood Directive both set ambitious targets.

Aquatic environments naturally have many assets to reduce the risk of flooding. Green infrastructures such as restoring floodplain connectivity to create flood expansion areas, giving space back to the river,setting back flood defenses, restoringthe natural morphology of rivers, reconnect wetlands to watercourses, limiting runoff, areactions that can be combined at a catchment scale and can help to decrease the pressure on flood protection structures by slowing down the flows. They can also help to improve water quality and biodiversity of aquatic environments.

These restoration actions can contribute to the protection of assets and people for the most frequent floods. They should be regardedas complementary tools to the flood risk management of more extreme flood events.

To implementation such a strategy, a starting point is to conduct a comprehensive analysis of the hydraulic, morphological and ecological functioning of the entire catchment to ensure that a consistent approach is taken and to be able to define several scenarios.Solidarity between the upstream and downstream parts of the catchment is one of the keys to the success such river management strategy.

The purpose of this presentation is to present and illustrate the policy adopted by the Rhone Mediterranean catchment agency and the French state around the following three principles:

- Giving more space to the river;
- Slowing down the flow of the river;
- Using the right scale for water management.

THE MANAGEMENT MODEL OF A STATE OF AQUATIC SYSTEM AND WATER QUALITY IN THE DNIEPER RIVER CASCADE RESERVOIRS

Vladimir Timchenko, Oksana Huliaieva

Institute of Hydrobiology, National Academy of Sciences of Ukraine, 12, Geroyev Stalingrada Avenue, Kiev 210, Ukraine 04210

E-mail: timchenkovm@gmail.com

Keywords: reservoirs, water quality, ecosystem state, management

1. Introduction

The objective of management of ecosystem state and water quality in the cascade reservoirs is to form of conditions in which self-purification processes prevail over effects of self-contamination and input of pollutants.

The results of ecohydrological research show that the most effective method of management is regulation of the water regime. It determines the intensity of many internal physical, chemical and biological ecosystem processes. Water regime of the Dnieper cascade six reservoirs can be regulated by the releases from their upstream hydroelectric power station (HEPS).

2. Materials and methods

Results of our earlier investigations in the Dnieper reservoirs clearly show that management problem of ecosystem reservoirs, including their river and lake sections, is topical.

At the present time there are results of ecohydrological researches concerning science-based management in the Dnieper delta and river section of the Dnieper reservoirs located below hydroelectric stations (Timchenko et al., 2000; Timchenko, Oksiyuk, 2002; Timchenko, 2006). The calculation method has been developed for ensuring the implementation of water quality management by hydropower releases. The essence of the method is as follows.

The leading indicators of ecosystem status and water quality are the labile organic matter content index (BOD_{tot}) or dissolved oxygen concentration (O_2) since the basic of water ecosystem functioning lies in the organic matter cycle. The dynamic of these indicators reflect relationship between ecosystem's primary production plus allochthonous inputs of organic matter, on the one hand, and its destruction by hydrobionts, on the other. If the biochemical oxygen demand is higher, the water is more polluted. When it is low, the self-purification processes dominate. A high dissolved oxygen level indicates on better water quality.

The ecosystems of the river section of the Dnieper reservoir include the main channel and in so called secondary network (anabranches, floodplain water bodies, and the floodplain itself). They take part in the processes determining water quality. The influence of each

subsystem depends upon functioning peculiarity as well as upon interchange of water masses, soluble and suspended matter and energy fluxes.

The model is based on the equation that takes into account the balance change of the labile organic matter or dissolved oxygen (integrated indicators of ecosystem condition and water quality) in the elementary volume of water during its passing in the main channel. The elementary volume is the daily volume of release through the dam at the upper hydropower station.

Change of leading indicators in the river section is defined as sum of changes of concentration of the labile organic matter or dissolved oxygen caused by internal water processes in the main channel, in floodplain water bodies, in floodplain and in the tributary flowing.

Each component of the balance take into consideration the intensity of the following processes: gross primary production by phytoplankton, phytobenthos, periphyton and macrophytes; oxygen demand consumed by organic matter catabolism (respiration) in the plankton, benthos, periphyton and macrophyte communities; outer organic matter load; atmospheric aeration and oxygen demand for the chemical oxidation of organic and inorganic matters (Timchenko et al.,2000; Timchenko, Oksiyuk, 2002).

The concept of management model of state of aquatic ecosystem of river section in the Dnieper cascade reservoir consists in regulation flow and intensity of water exchange by hydropower releases.

3. Theory

We have already confirmed that state of ecosystems of the river section of the Dnieper reservoirs is determined by condition of ecosystems functioning of the main stream and so called secondary network. It may be supposed that the same is true also for lake section of the Dnieper reservoirs which we have divided into two zones: transit and non-transit. In this case transit zone is taken as main stream and not-transit zone is considered secondary network.

The division of lake section of the cascade reservoir on two zones is necessary because the physical, chemical and biological processes of ecosystem functioning and the formation of water quality in these areas are fundamentally different. The primary reason for this difference is the various hydrodynamic conditions and unequal water exchange. In the transit zone the water exchange and mixing of water masses occur as a result of flow and wind currents. In the not-transit zone the flow currents are insignificant. Shallowness is the main factor impacting on the functioning of not-transit zones ecosystems.

Ecological-hydrodynamic regionalization of the Dnieper river cascade reservoirs was made possible by use mathematical current-modeling method of Felzenbaum (Felzenbaum, 1960; Voltsinger, Piaskovskiy, 1968).

As a result we obtained schemes of currents' functions (water discharges) distribution in the water area, and currents' vectors at any depth or averaged by vertical. At this practically all factors influencing currents are taken into account (water inflow and outflow, wind direction and velocity, morphology and roughness of the riverbed, banks configuration).

Transit and not-transit zones in the Dnieper cascade reservoirs were allocated in the following way (Timchenko et al., 2010). Schemes of currents' functions were received for the calm weather. These are situations when the main factors to influence water masses movement are the HEPS flushes and water income from tributaries. Just at such conditions it is possible to allocate zones.

At establishment of borders between transit and not-transit zones it was accepted that through the not-transit zone more that 1% of discharge may be transported. This criterion is conditional; however its appropriateness was indirectly confirmed by comparison of many hydrophysical, hydrochemical and hydrobiological characteristics of the water masses in the given zones. In fact, conditions of the aquatic environment quality forming and biotic components functioning in these zones are different in essence.

Schemes of ecological-hydrodynamic regionalization of the Dnieper cascade reservoir have been presented in our paper (Timchenko, 2010). They are based on highly accurate digital cartographical basis and be used for any kind of ecological assessments, calculations and forecasts.

But the balance method is better to use for extreme conditions in connection with significant transformation of the disturbance waves by hydropower releases in the lake section of reservoirs. When low dissolved oxygen concentration in winter and summer observed resulting from near atmospheric and photosynthetic oxygenation and by continued aerobic respiration of hydrobionts, decomposition and chemical oxidation. In such conditions topical goal is the improvement of the water quality.

Under the present regime of Dnieper HEPSs operation the water exchange between transit and not-transit zones is generated by wind currents and waves. They are hydrodynamic phenomena, which are not artificially controlled. If the dissolved oxygen concentrations in main channel are low, they can be raised by raising water level in the lake section reservoirs due to nonsynchronous operation of below and above located hydropower station. Results of calculations (Timchenko, Linnik, 2003) show that one cycle of artificial water level rise in Kaniv reservoir of 0.5 m will result in oxygen content increase to 0.16 $mg \times dm^{-3}$ in result flowing water from floodplain, where aquatic vegetation grows and produces oxygen by photosynthesis.

Thus, the task of a reservoir water quality management usually should be based on assessment degree of transformation of environmental indicators of water masses during passing in the reservoir. This task can be solved on basis of balance method. Considering that the fundamental principles of the model are true, we note that the model should use a limited number of input parameters, in particular the number of estimated parts needs to reduce.

We propose a modeling approach that evaluates these processes in two settlement areas (river and lake section) and in two zones (transit and not-transit) in each of the reservoirs. For simplicity, we accepted a condition that in the river the main channel is transit zone and secondary network is not-transit zone.

According to such dividing principle, the change of the leading indicators of water quality masses passing the reservoir is described by the equation:

$$\Delta C = \frac{\tau_r \cdot W_{tr,r}}{W_r}(A_{tr,r} - R_{tr,r} + At_{tr,r} - G_{tr,r}) +$$

$$+ \frac{\tau_r W_{ntr,r}}{W_r}(A_{ntr,r} - R_{ntr,r} + At_{ntr,r} - G_{ntr,r}) + \frac{\tau_r W_{tf,r}}{W_r}(C_{tf,r} - C_{in,r}) +$$

$$+ \frac{\tau_l W_{tr,l}}{W_l}(A_{tr,l} - R_{tr,l} - At_{tr,l} - G_{tr,l}) +$$

$$+ \frac{\tau_l \cdot W_{nt,l}}{W_l}(A_{ntr,l} - R_{ntr,l} + At_{ntr,l} - G_{ntr,l}) + \frac{\tau_l \cdot W_{tf,l}}{W_l}(C_{tf,l} - C_{in,l}),$$

where:

τ_r, τ_l – the lag time presence of water at river and lakes sections of reservoirs, day

W_r, W_l – the general volume of water flow at river and lake sections, m^3 day^{-1};

$W_{tr,r}$; $W_{tr,l}$ – volume of water flow at transit zones of river and lake sections, $m^3 \cdot day^{-1}$;

$W_{ntr,r}$; $W_{ntr,l}$ – the same at not-transit zones, $m^3 \cdot day^{-1}$;

$W_{tf,r}$; $W_{tf,l}$ – the tributary flowing into river and lake sections, $m^3 \cdot day^{-1}$;

$A_{tr,r}$; $A_{ntr,r}$ – the photosyntetic oxygen production (gross primary prodyction of organic matter in transit and not-transit zones in river section, mg $O_2 \times dm^{-3} day^{-1}$;

$A_{tr,l}$; $A_{ntr,l}$ – the same in lake section;

$R_{tr,r}$; $R_{ntr,r}$ – the destruction of organic substance in transit and not-transit zones in river section, mg $O_2 \times dm^{-3}$ day^{-1};

$R_{tr,l}$; $R_{ntr,l}$ – the same in lake section;

$At_{tr,r}$; $At_{ntr,r}$; $At_{tr,l}$; $At_{ntr,l}$ – the atmospheric aeration at specified sections and zones, mg $O_2 \times dm^{-3}$ day^{-1};

$G_{tr,r}$; $G_{ntr,r}$; $G_{tr,l}$; $G_{ntr,l}$ – the oxygen demand for the chemical oxidation of organic and inorganic matter at specified sections and zones, mg $O_2 \times dm^{-3}$ day^{-1};

$C_{tf,r}$; $C_{tf,l}$ – the dissolved oxygen concentration in the tributary flowing to river and lake sections, mg $O_2 \times dm^{-3}$;

$C_{in,r}$; $C_{in,l}$ – the initial dissolved oxygen concentration in river and lake sections, mg $O_2 \times dm^{-3}$.

In the reduced model the main regulated parameters are volume of flow and internal water exchange in the sections and zones. They depend on regime and volume of HEPS releases. The tributary flowing is initial parameter too, it is observed by government hydrometeorological network. Volumes of water flow at transit and not-transit zones of river and lake section are calculated by hydrological techniques including mentioned mathematical current-modeling method. The means of definition of the rest of chemical and biological parameters reduced equation has been expounded in our article earlier (Timchenko, Oksiyuk, 2002).

Conclusion

The basic idea of ecosystem management in the Dnieper River cascade reservoir is to regulate of volume of flow and internal water exchange in the sections and zones by HEPS releases.

Functional characteristics of sections and zones of water ecosystems have been established by the results of long-term hydrobiological researches in regional water bodies.

Thus, ecological regulation of operation regime of Dnieper reservoirs cascade is principal important problem which need integrated study. Technical approaches which stated above are used for design the environmental requirements for New Rules of cascade operation.

References

Timchenko, V.M., Oksiyuk, O.P., Gore, I. 2000. A model for ecosystem state and water quality management in the Dnieper River delta. Ecol. Eng. 16. 119–125.

Timchenko V., Oksiyuk O. 2002. Ecosystem condition and water quality control at impounded sections of rivers by the regulated hydrological regime. //Ecohydrology and Hydrobiology. 2, # 1–4. 259–264.

Timchenko, O.V., Linnik, P.N. 2003. Kisnevy regim Kanivskogo vodoskhovischa i mojlivi shlyakhy yogo polipshennya v kritichnikh umovakh. (Oxigen regime of Kanev reservoir and possible ways of its improvement in critical conditions) // Works of Ukr.SIHMI. 251. Kiev, Nika centre. 204 pp. [Ukr.].

Timchenko V.M. 2006. Ecologicheskaya hidrologiya vodoyomov Ukrainy. (Ecological hydrology of water bodies of Ukraine) Kiev, Naukova dumka. 384 pp. [Rus.].

Timchenko,V.M. 2010. Water-exchange processes as factor of the energy fluxes formation in ecosystems of the Dnieper reservoirs. // Hydrobiological Journal 46. 91-105.

Timchenko V.M., Timchenko O.V., Huliaieva O.A., Holod'ko O.P , Vandyuk N.S. 2010. Ecologo-hidrodinamichne rayonuvannya cascadnykh dolynnykh vodoskhovisch (The eological and hydrodynamic regionalization of the valley cascade reservoirs) // Hydrology, hydrochevistry and hydroecology. 2(19).Kyiv, Obrii. 23–29. [Ukr.].

Voltsinger, N.Ye., Piaskovskiy. 1968. Osnovniye okeanologichaskiye zadachi teorii melkoy vody. (The principal oceanologic task of the shallow water theore) Leningrad, Gidrometeoizdat Pres. 299 pp. [Rus.].

Felzenbaum, A.I. 1960. Teoreticheskiye osnovy i metody rascheta ustanovivshikhsia morskikh techeniy.(Theoretical principles and methods of calculation of the stable marine currents) Moscow, Academy of Sciences publishing House. 122 pp. [Rus.].

ARIDIZATION PROCESSES WITH INCREASING AVERAGE ANNUAL RAINFALL AT A DESERT FRINGE, NORTHERN NEGEV DESERT, ISRAEL.

Aaron Yair
Department of Geography, Hebrew University of Jerusalem
Israel
e-mail: aaron.yair@mail.huji.ac.il

Dryland areas are usually regarded as highly sensitive to climate change. A positive relationship between average annual rainfall and environmental variables is often assumed by many scientists for semi-arid and arid areas. However; existing global models are not yet capable of predicting accurately the evolution of regional climates and their possible impact on the environment. Furthermore, the global models fail to address an important issue: with decreasing average annual rainfall water resources may be highly dependent on the relationships between rainfall and surface properties which greatly influence the degree to which water will percolate or will be transformed into runoff, thereby significantly affecting the spatial redistribution of water resources. In other words, a given climate change would be expected to have differential effects in a rocky area, in a loess covered area or in a sandy area. The northern Negev area offers unique conditions for the study of the possible effects of the foreseen climate change along rainfall gradient under changing surface conditions. Two case studies are considered in the study. The first deals with the environmental effects of loess penetration into the area, during a wet climatic phase. The second considers the differential effects of biological topsoil crusts on the water regime along a rainfall gradient in a sandy area. The rainfall gradient is accompanied by other gradients (geomorphological, pedological, biological, etc). Data obtained draw attention to the complex relationships between annual rainfall, surface properties, water availability and ecosystem structure. In the two areas considered the increase in the average annual had a negative effect on the water resources and related ecological properties

DUAL REGULATION AND ECOSYSTEM BIOTECHNOLOGIES FOR THE ENHANCEMENT OF ECOHYDROLOGICAL POTENTIAL OF THE CATCHMENTS – WATER BIODIVERSITY, ECOSYSTEM SERVICES AND RESILIENCE

Maciej Zalewski

European Regional Centre for Ecohydrology of the Polish Academy of Sciences

Department of Applied Ecology, University of Lodz

The one of the most important and poorly recognised threats for biosphere sustainability in the era of climatic changes has been the acceleration of the water outflow from the catchment by the reduction of the diversified biomass mosaic, especially in an agricultural landscape and the loss of organic matter in soils. These negative processes have been further increased by over fertilisation by nitrogen, phosphorus and pollution by pesticides, which due to the unification of catchment landscapes have been transferred into freshwater ecosystems and costal zones in great amounts, causing secondary pollution - algal blooms and bioaccumulation of toxic substances .

In order to reverse those forms of cumulative intermediate impacts, which often are major factors of degradation the ecological potential at catchments, profound understanding of the water - biota interplay is most important. This is because water has been the major determinant of ecosystems structure. Moreover, the dynamics of hydrological cycle combined with temperature patterns determine the productivity and biodiversity of ecosystems, both terrestrial and aquatic. On the other hand, biocenosis modifies the hydrological cycle to great extent, especially increasing water retentiveness in the catchment landscape and reduces stochastic character of hydrological pulses.

The above knowledge has been a fundamental element of the integrative science – Ecohydrology, which by identifying a plethora of water - biota interactions, provides a scientific background for the development and quantification of problem-solving methodology: principles of EH “dual regulation” and EH biotechnologies. The above EH framework serves not only to mitigate intermediate forms of impact but also to increase the ecological potential of a river basin expressed by a multi-dimensional goal - Water, Biodiversity, Ecosystem Services for Society and Resilience to climatic changes (WBSR) , which helps to harmonise the enhanced ecosystem potential with society needs and, in turn, achieve sustainability of river basins.

ECOHYDROLOGICAL IMPLEMENTATION OF A SMALL FLOODPLAIN RESERVOIR – FIRST PRINCIPLE: MONITORING OF ECOLOGICAL AND HYDROLOGICAL PROCESSES

Kamila Belka , European Regional Centre for Ecohydrology of the Polish Academy of Sciences, Łódź, Poland, k.belka@erce.unesco.lodz.pl
Edyta Kiedrzyńska, European Regional Centre for Ecohydrology of the Polish Academy of Sciences, and Department of Applied Ecology, University of Łódź, Łódź Poland, edytkied@biol.uni.lodz.pl
Marcin Kiedrzyński, Department of Geobotany and Plant Ecology, University of Łódź, Poland, kiedmar@biol.uni.lodz.pl
Maciej Zalewski, European Regional Centre for Ecohydrology of the Polish Academy of Sciences, and Department of Applied Ecology, University of Łódź, m.zalewski@erce.unesco.lodz.pl

Key words (5 at the most)

Ecohydrology, reservoir construction, floodplain development, landscape resilience enhancement

(sub-topic: 1.3. Ecohydrology system solution and ecological engineering for the enhancement of water and ecosystem resilience and ecosystem services)

Topic of this work

This research addresses the ecohydrological investigation of existing hydrological and ecological conditions of an immediate catchment of a side river branch subject to the development plans of the local government. The local plans provision location of a recreational reservoir in a floodplain area, however, the conventional hydrotechnical conceptual study prepared for this investment does not include important ecohydrological conditions to prevent against future water quality problems. Thus, the local government commissioned the ecohydrological study leading to the more sustainable management of this area.

Research question (or operational application)

The purpose of this study is to analyze basic ecological and hydrological characteristics that would allow to determine the baseline conditions for the planned future reservoir location and predict the expected freshwater and terrestrial ecosystems' response to its development. The main goal of the reservoir location will be to simultaneously enhance water retention in the landscape and biodiversity leading to increased ecosystem services and resilience of the system (WBSR – Water, Biodiversity, Ecosystem Services and Resilience) in the condition of climate change.

Originality of this work

According to long-term data analysis the drought periods are getting more and more severe in the latest decades, and they impose a major impact on fish communities. That is why construction of a small reservoir will play a dual role – will provide a refuge for aquatic organisms during critical periods of drought and in the winter time, and will reduce stochastic character of the hydrological cycle of the catchment. The challenge and opportunity of this work is the possibility to shape ecohydrological processes in order to enhance the WBSR components in a real case study with cooperation with the local government and in the framework of existing legal regulations. The key prerequisites to achieve WBSR of the ecosystem are: understanding of the condensing and dilution patterns of hydrographs; application of biotechnologies to improve nutrients circulation in the ecosystem; and optimizing the hydrodynamics of the lake by proper shaping of its shores and the

bowl. This will allow to decrease the loads of organic matter, nutrients and other pollutants to the reservoir and to minimize the probability of occurrence of toxic algal blooms in the reservoir.

Data and / or method

The present study is a preliminary assessment of the ecological and hydrological processes occurring in the vicinity of a side branch of the Grabia river in Łask city, Poland, where the planned reservoir shall be constructed. The following environmental parameters are being monitored over a period of 6 months (May - October 2015): discharge, rainfall, air and water temperature, physico-chemical parameters for surface and ground waters (including concentration of dissolved forms of nitrogen and phosphorous: $P\text{-}PO_4^-$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$ and ions: F^-, Cl^-, Br^-, SO_4^{2-}, Li^+, Na^+, K^+, Mg^{2+} and Ca^{2+}),as well as concentration of total phosphorous (TP), dissolved total phosphorous (DP)and suspended matter. The existing sources of pollution are also analysed, including agricultural, industrial and domestic dispersed and point sources of pollution. The investigation is accompanied with a general environmental analysis, including geological, geomorphological and pedological conditions, as well as climatic and hydrological characteristics. The land use / land cover structure analysis and groundwater susceptibility for pollution was analysed in the whole catchment scale on the basis of existing information; they are important for a general assessment of the water quality potential. The important dimension of this project is its vicinity to the Natura 2000 area (PLH100021 Grabia river valley), and its inclusion in a regional form of legal protection concerning landscape and nature protection. Therefore the natural vegetation was mapped and evaluated at the extent indicated by the local regulations (spatial planning documents) in order to assess its importance for the existing forms of protection, as well as existing fauna was scanned for existence of protected species.

Main results

The results are of preliminary character and the research is underway.

Conclusion

Realization of the project will pave the way for a more sustainable small reservoir construction harmonizing the nature potential with human needs.

Aknowledgements

The authors would like to acknowledge Dr Robert Słomczyński and Bartosz Lesner for realizing a preliminary study of the fauna assessment in the area of the planned reservoir. Dr Ilona Gągała is acknowledged for instruction and guidance in ion chromatography analysis.

2- Methods and models for the determination of environmental flows in rivers and estuaries

ENVIRONMENTAL CONDITION OF CATCHMENT BASIN OF DEBED RIVER BETWEEN 2010-2013 (APRIL-MAY AND SEPTEMBER-OCTOBER)

Inga Badasyan, bingae25@gmail.com

The Institute of Geological Sciences of National academy of Sciences and Environmental Impact Monitoring Centre of Armenia

Key words
Biodiversity, geological mining, benthic macro invertebrate, water quality, zoo benthos.

Abstract

The Republic of Armenia has large rivers, Arax, Metsamor, Hrazdan, Arpa, Vorotan, Azat, Akhuryan, Debed and many others. These rivers have 100km and have big catchment basin. Therefore, we have done research on catchment basin of Debed river between 2010-2013.

The measurement of the natural processes is related to the water flow. The maximum level in the rivers is seen in May, while the lowest level seen in summer and winter. The second level rise occurs in September and October.

The water quality of rivers and lakes effects badly on the availability of hydraulic structures, natural disasters and when water use of non-registered. The pollution of water's surface is a global problem, which depends on population growth, with intensive industry and economic development. On aquatic organisms the change of temperature has a huge impact on their development and biological activity, the water pH value is an important indicator of water quality. The normal growth, development and viability of aquatic organisms, as well as many chemical and biological processes depend on the water pH value.

The Standard Operation Procedure method is important for biodiversity and water quality control. The benthic macroinvertebrates are the best indicators of water quality.

Every year the Institute of Geological Sciences of Armenia and Environmental Impact Monitoring Centre are doing research on the hydroecological and hydrochemical characters for bottom fauna in Debed river.

1. Introduction

The sampling time is important for benthic macroinvertebrates, for that reason we have chosen in the spring (abundant flow of the river, the beginning of the vegetation season) and autumn (the flow of river is scarce).

The zoo benthos is a good indicator for a chromic pollution and aquatic ecosystems. The zoo benthos by tropic properties is considered sensitive organisms in aquatic ecosystems. The Oligochaeta, Mollusca, Chironomidae are total taxon indicator of biodiversity and miomass, as well as the numbers. In bottom fauna of Debed river under flowing is decrying, that the number of individuals and biomass population decrease.

In the bottom fauna of Debed river is found nearly 30 species in 2012. The Plecoptera's larvae live in the clean and fast flow river. Some adults of Plecoptera are short term, and lot of live 2-3 month. The Trichoptera lives almost in all types of waters, lakes, rivers and streams, especially where are different types of sobstrates. In summer, when the temperature of water passes optimum

limit, then falls in the intensity of their growth and reproduction. The Mollusca often resumptions breed in autumn.

Research results can be applied to studies of monitoring water quality in the rivers and allow for rate changes and to predict possible future changes in the nature of the lake.

2. Materials and Methods

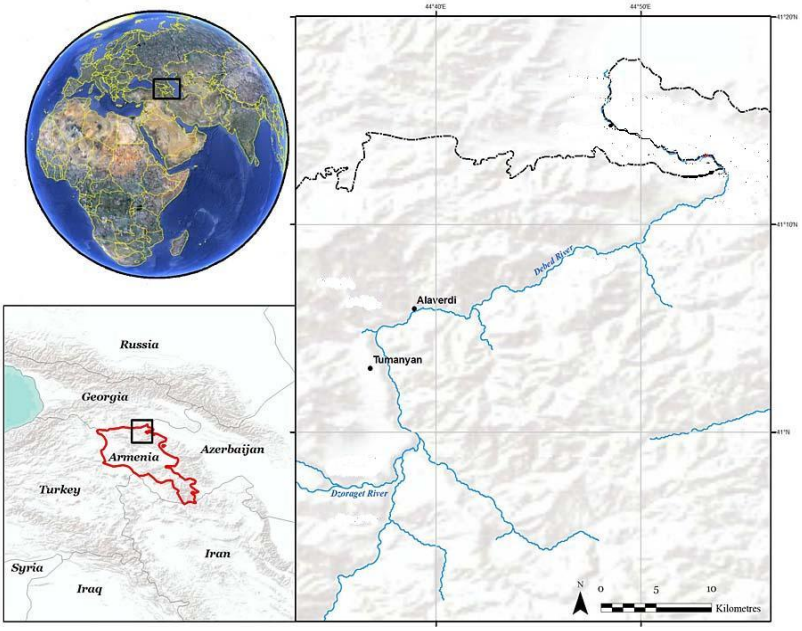
For macroinvertebrates sampling, the modified multi-habitat sampling method was used that is based on the techniques in accordance with AQEM/STAR methodology (EPA 841-B-99002). Ten plus one replicates were sampled per monitoring site with sizes 30 x 30 cm (0,5 mm mesh size). The replicates (sampling frames) were selected after detailed habitat observation according to the percentage ratio of the main bottom substrates. The position of the sampling net was on the bottom against the river flow to make wash sampling (stones, gravel, macrophytes) and kick sampling (stones, pebbles, gravel, sand, silt, etc.) (*EN ISO 10870:2012*). After removal large materials and organisms the samples were fixed with the ethanol 80%-96% and with 5% formaldehyde. And stored in the cooling box and delivered to the laboratory for sorting and identification.

Measurement of pH is of the most important and used test in water chemistry. pH is used in alkalinity and carbon dioxide measurements and many other acid-base equilibria. At a given temperature the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion activity (ISO 10523:2008).

The dissolved trace elements are determined by inductively coupled plasma mass spectrometric method and Elan 9000 ICP-MS equipment. The samples are conserved by 1% nitric acid. The internal standart is indium (10 mg/L) and the 99,999 % argone is used as ion source (ISO 17294-2:2003).

The biochemical oxigen demand is determined by after 5 days (BOD_5) method. The sample is estimated in advance and after 5 days in 200C incubated sample of water. The difference between the content of the decision (ISO 5815-2:2003).

The nitrite concentration of standard solution is measured by spectrophotometric method (Shimadzu UV- 1650PC). We are used Griess reagent (α-naphthyl, sulfanilic acid), deionized water for Calibration of standard solution. As a result of the complex interaction of the compound with pink paint was determined by the concentration of nitrite (choosing 524nm wavelength and 10cm cuvette) (ISO 6777:1984).



2.1. Study Area

The Debed is a part of the Kur-Araks basin (which is located in South Caucasus). It is the second most abundant river in Armenia (second to Araks). The length of river is 178 km, the height is 250 m, and catchment basin's area is 4050 km^2. The river is changing from sea level between 390 - 3200. The climate is quite humid. The annual precipitations are changing from 500 to 800 mm [5].

The household, agricultural and

industrial is affecting for water quality on Debed river.
The Debed River Basin is between Armenia and Georgia. The surface flow out flowing from these areas will bring various toxic substances thus polluting the environment and Trans boundary Debed River. This is Picture1.Map of Armenia and Debed rive the first reason for the high pollution of water. Therefore we have chosen this river, and look picture 1 [7].

2.2. Calculation Methods

The value of Biotic Index (BI) is determined all taxonomic groups and families to the amount. The importance of this method lies in the fact that the state is determined by water pollution.
The pointer of BI:

$$\text{Biotic Index (BI)} = \sum \frac{(n)(a)}{N}$$

where: N = number of individuals in the sample
n = number of individuals of each taxon
a = pollution-tolerance value assigned to that taxon [1].

The mathematical calculation method is also included, which will be implemented as follows:

- The benthic invertebrates are important for classification (Order-Family-Genus-Species),
- The taxonomic groups to the count and added together,
- The results are registering to the chart.

3. Results

3.1. Results of physiochemical analysis

Universal correctness and accuracy of the data collected, as well as to ensure the reliability and comparability involved laboratories used by transparent and well-defined quality control analytical procedures. Moreover, interlaboratory calibration tests were conducted in two independent for Quality Assurance (QA) and Quality Control (QC) System of laboratories, and all sampling stations were investigated by physico-chemical parameters (pH, BOD_5., Electrical Cond., Na, Mg, Ca, Fe, Ni, Zn, As, ClO_2, NO_2, PO_4) (Table 1.).

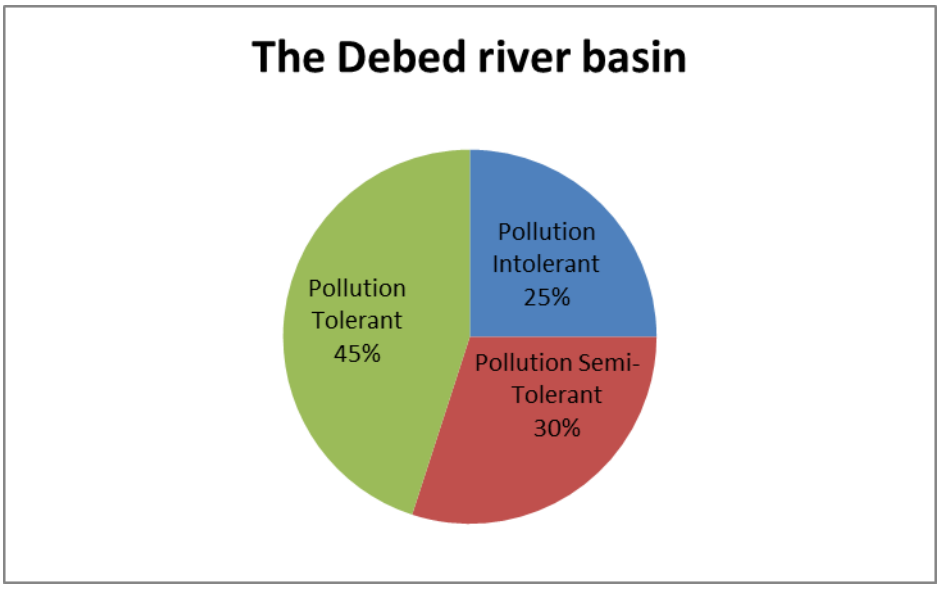
Table 1. The average value of physicochemical analysis results of water sample

Year	Month	pH value	BOD_5. mg/L	Electrical Cond. mSim/cm2	Na mg/L	Mg mg/L	Ca mg/L	Fe mg/L	Ni mg/L	Zn mg/L	As mg/L	ClO_2 mg/L	NO_2 mg/L	PO_4 mg/L
2010	May	8,08	7,2	237,50	12,80	5,22	23,04	0,40	0,003	0,114	0,001	2,67	0,07	0,12
	October	8,4	2,48	326,67	16,24	10,80	49,92	0,19	0,001	0,006	0,001	8,13	16,29	0,04
2011	May	8,06	1,81	230,86	5,17	3,87	20,20	0,36	0,002	0,005	0,001	2,47	5,25	0,11
	October	7,69	2,88	412,67	16,71	9,82	51,25	0,17	0,002	0,003	0,001	6,73	16,44	0,33
2012	May	8,25	2,25	228,67	8,24	4,77	29,36	0,93	0,004	0,019	0,001	2,92	6,10	0,13
	October	8,10	3,33	416,43	11,34	8,38	44,93	0,76	0,002	0,022	0,002	6,73	13,15	0,09
2013	May	7,66	2,57	225,00	7,91	4,73	29,63	0,70	0,001	0,008	0,001	3,87	4,55	0,21

	October	7,80	3,33	416,43	12,01	9,76	44,93	0,10	0,002	0,002	0,001	6,73	12,69	0,22

3.2. Results of benthic macro invertebrates and phytoplankton research

We in basically found during the research in the following insects, Trichoptera, Ephemeroptera, Simulidae, Chironomidae, Coleoptera, Blepharoceridae, Rhagionidae, Gammaridae, Hirudinea.
In bottom fauna of Debed river's under flowing is decrying, that the number of individuals and biomass population decrease [2].
The biological monitoring is important for water quality and for this we were used macroinvertebrates and phytoplankton as biological indicator [3].
In the bottom fauna of Debed river is found nearly 25 species in 2010 [4]. In the bottom fauna of Debed river is found nearly 30 species in 2012.On the stones generally is meeting to the Polipedilum (Kieffer, 1912), Rheotanyttarsus, Eukiefferiella (Thienemann, 1926), Psectrocladius (Kieffer, 1906) species. On the macrophyte sunk discovered to the Chironomus thummi, Trichockadius algarum, Thienemanniella (Kieffer, 1911) Pelopia fulva species. On the silt habitat of sand is meeting to the Cryptochironomus (Kieffer, 1918), Paracladopelma (Harnisch, 1923), Stictochironomus (Kieffer, 1919). In the bottom fauna of Debed river is found nearly 46 species in 2013 . Aquatic macroinvertebrates can be used as Bioindicators. The presence of pollution intolerant organisms indicates a healthy stream with very little pollution. Pollution intolerant organisms found mayfly larva, stonefly larva. Pollution semi – tolerant organisms was found dragonfly larva. Pollution tolerant organisms found aquatic worm (Diagram 1.).



1. The bio-indicators of the Debed river basin (2010-2013)

Between 2012-2013, the scientists of hydrological institute found into phytoplankton coexistence of algae to the 8 class, 6 order, 35 family, 61 genus, 184 species (Table 2) [6].

Table 2. The taxonomic of phytoplankon coexistence in Debed river

Diatom algae	Class	Order	Family	Genus	Species
Bacillariophyta	2	5	12	32	109
Chlorophyta	2	5	13	16	39
Cyanophyta	2	3	7	10	31
Euglenophyta	1	1	1	1	2

Xanthophyta	8	16	35	61	184

Discussion

One improvement would be to visit the Debed river to collect macro invertebrates and to do chemical testing. Perhaps, if we go to the site, our group can see whether chemical testing affected the macro invertebrates.

Aquatic macroinvertebrates can be used as Bio-indicators. This Bio-indicators are organized into 3 categories:

1. Pollution Intolerant,
2. Pollution Semi-Tolerant,
3. Pollution Tolerant.

The presence of pollution intolerant organisms indicates a healthy stream with very little pollution. Pollution intolerant organisms are found mayfly larva, stonefly larva. Pollution semi – tolerant organisms is found dragonfly larva. Pollution tolerant organisms is found aquatic worm.

The biotic index values were significantly different because the macroinvertebrates have different tolerances to pollution and nutrient levels, and different dissolved oxygen needs.

If the macroinvertebrates have trouble surviving in their habitats, then there might be less prey for the fish, which could cut the supply of food for humans.

Conclusions

Research was carried out to determine the effects of anthropogenic addition to the impact of geological changes. For example, geological mining, underground water's radioactive pollution and pollution of chemical residues influence on the environment. A mining and geological engineer is someone who designs mines for the safe and efficient removal of minerals.

Study results showed that the of water quality of Debed river has been changed. Because from chemical composition of water changed biodiversity in river.

For that reason annual monitoring for water quality needs to be done.

Acknowledgements

Directorate Environmental Impact Monitoring centre of Armenia and Scientists of The Institute of Geological Sciences of NAS RA,

References

1. A Water-Quality Assessment Using Aquatic Macroinvertebrates from Streams of the Long Pine Creek Watershed in Brown County, Nebraska, Transactions of the Nebraska Academy of Sciences and Affiliated Societies.
2. Danielyan A.A., Grogoryan K.V., Dallaqyan M.R., Ghukasyan E. Kh. 2008,The bottom fauna diversity in catchment area of Debed river.
3. Emere M. C., Nasiru C. E, 2009, Macroinvertebrates as Indicators of The Water Quality of an Urbanized Stream, Kaduna Nigeria, Nature and Science.
4. Lenore S. Clesceri, Arnold E. Greengorg, Andrew D. Eaton 1998, Standard methods for examination of water and wastewater 20th Edition, USA.
5. Markosyan A., Nazaryan G., 2003, Water Resource Management, Yerevan.
6. Svetoslav Cheshmedjiev, 2013, Rapid Biological Assessment (RBA) based on analysis of benthic macroinvertebrate communities.
7. http://www.antiquity.ac.uk/projgall/egeland329/

FLOWS OF FRESHWATER AND ANTROPHOGENIG NUTRIENTS TO VITÓRIA BAY ESTUARINE SYSTEMS (SE BRAZIL): COUPLING FLUVIAL-COASTAL ECOCYSTEMS

Gilberto Fonseca Barroso[1], Fernando Jakes Teubner Jr[2], Tatiana Cappelletti[2], Thayana Leite[2], Decimara Nunes[2], Eduardo Schettini Costa[1], Renato Rodrigues Neto[1], Ana Teresa Lima[1]

[1]Federal University of Espírito Santo – UFES, Department of Oceanography and Ecology; [2]UFES' Graduate Program in Environmental Oceanography E-mail: gilberto.barroso@ufes.br

Key words: river basin, estuary, fluvial flows, emission rates, nutrients

(Topic 1: Approaches to modeling and management of eco-hydrological processes)

Topic of this work

The quantity, quality, timing of continental hydrologic flows and the hydrological connectivity with coastal ocean control estuarine hydrodynamics. Estuarine distributions of salinity, sediments, dissolved and suspended particulate materials, in turn affect the distribution of biological communities, primary and secondary production and, therefore, ecosystem services. Hydrological flows from river basins are subject to natural drivers such as climate and basin morphometry, hydrography and hydrology, and also by socioeconomic features of drainage basins. Ideally, the development of hydrological models of water and materials from river basins to estuarine ecosystems ought to address natural variability of flows, without anthropogenic interferences. The best approach would rely on historical datasets of flows of freshwater, sediments, nutrients and contaminants, which are only available for very few sites, most of them on temperate latitudes. This study presents a framework to estimate river discharge and nutrients (N and P) budgets of a tropical coupled fluvial-coastal ecosystem based on climatic factors, coastal river basins physiography, hydrology and socioeconomic features of river basins with poor hydrological and hydrochemistry data.

Research question (or operational application)

In what degree catchment morphometry, climate, population density affects water and nutrient budgets to estuarine ecosystems? Does anthropogenic sources are more important than natural sources? Does estimated freshwater discharges and emission rates are effective approaches to support water management?

Originality of this work

Our approach aims to provide a more concise framework to understand the relationships of catchment morphometry, land use and hydrology on freshwater and nutrient flows to coastal ecosystems in hydrological data poor river basins. In order to achieve that, our research program seeks to estimate flows of water and emissions rates of N and P from natural (i.e., atmospheric inputs and soil denudation) and anthropogenic sources (i.e., wastewater, urban runoff, agriculture, and livestock farming). The results presented deal with basins discharges and anthropogenic sources of N and P on sewage.

Data and / or method The Vitória Bay Estuarine System – VBES (41.8 km^2), in the Metropolitan area of Great Vitória, southeast Brazil, is shallow estuary with microtidal/semi-diurnal regime and with 60 % of the area covered with mangrove ecosystems. Catchment delimitations were based on processing of DEM model (30 m resolution), yielding in 10 drainage basins (1.921.2 km^2). A set of regional georeferenced data of hydrography, relief, climate (rainfall and temperature), population (counting sectors) were analyzed to estimate river basins mean annual freshwater discharge and loads of N and P. Water discharges were computed assuming that rainfall equals evapotranspiration and runoff empirical models of river basins discharges were estimated based on a regional dataset of monthly precipitation and temperature obtained during 30 years.

$$Q = \iint r \times \frac{\Delta f}{r}\, dA$$

Where, Q is the discharge in m^3/s, Δf is the runoff in mm/yr, r is the precipitation (mm/yr) and the non-dimensional quantity $\frac{\Delta f}{r}$ is the runoff ratio, which is the fraction of rainfall converted in runoff, and corrected by evapotranspiration (mm/yr).

Emissions factors of N and P from anthropogenic sources (i.e., wastewater) were based on equations proposed by De Paula et al., (*in press*):

$$L_{Ww}^{N,P} = \sum_{i=1}^{5}\left(\frac{\rho_{Ww}.P_{ui}.Q_{ui}.\beta.365}{10^9}\right) + \sum_{i=1}^{60}\left(\frac{\rho_{Ww}.P_{ri}.Q_{ri}.\beta.365}{10^9}\right)$$

Where, $L_{Ww}^{N,P}$ is the is the load of nutrients from wastewater of urban and rural areas of each basin, rWw is the concentration of N or P in raw sewage (52 and 15mg/L, respectively); Pui and Pr i are the urban and rural populations based on 2010 population counting in each basin, respectively; Qui and Qr i are the urban and rural water consumption per capita, 85 and 114,2 L/inhabitants, respectively; and b is the water/sewage rate of return (80 %). Water consumption/sewage return rates and N and P contents in sewage were based on national standards.

Main results The mean annual freshwater flow form 10 catchments to VBES yield 171.2 m^3 x 10^6, with a specific discharge of 89.1 m^3 x $10^3/km^2$. In 2010, human population in the catchment was 1,075,683 inhabitants, which 96.1 % as urban residents. The total loads of Total N and P from sewage were 1000.9 and 288.9 t/yr, respectively.

ConclusionThe use of population counting based on census sectors and the integration of this polygon vectors improved the quantification of basin inhabitants. Thus, loads estimates are more accurate. The study approach provides valuable information about water and nutrient loads to coastal ecosystems under poor hydrological and hydrochemistry data conditions. It is expected that this knowledge provide foundations to regional water management programs.

Acknowledgements

This paper was written in the context of the MCT/FINEP CT-Hidro 01/2010 – Project Network of Aquatic Systems Hydrodynamic and Environmental Monitoring – REHMAMSA and FACITEC 04/2008 Integrated Assessment of Estuarine Ecosystems: Case study of Vitória Bay Estuarine System.

TESTING THE IMPACT OF STORMWATER SOURCE-CONTROL MEASURES ON THE ECOHYDRAULIC RESPONSE OF AN URBAN STREAM

Matthew J Burns, School of Ecosystem & Forest Sciences (Waterway Ecosystem Research Group), University of Melbourne (matthew.burns@unimelb.edu.au)
Jochen E Schubert, Department of Civil and Environmental Engineering, University of California (Irvine) (j.schubert@uci.edu)
Tim D Fletcher (same affiliation as Burns, tim.fletcher@unimelb.edu.au)
Brett F Sanders (same affiliation as Schubert, bsanders@uci.edu)

Key words (5 at the most)

Urban ecohydrology, stormwater retention, geomorphology, hydrodynamic (sub topics: 2.6 and 2.7)

Topic of this work

Impact of catchment-scale stormwater retention on bed shear stress.

Research question (or operational application)

Conventional stormwater drainage increases the frequency and magnitude of high-flow events (Burns et al. 2012). Such events have been implicated as a major driver of the ecological degradation of urban streams (Walsh et al. 2005). They begin soon after rainfall, and discharge can be orders of magnitude greater than antecedent flow. In addition to mobilizing a wide range of sediments, thus resulting in a sediment-poor benthos (and a loss of habitat), they are also likely to cause substantial drift losses of flow-sensitive macroinvertebrates. The loss of sensitive macroinvertebrates in urban streams may thus be due to these two interrelated factors. Alternative approaches to urban stormwater management aim to restore or protect natural flow regimes, using stormwater source-control measures (SCMs). In theory, the use of SCMs has the potential to impact high-flow hydrology such that bed shear stress is reduced to more natural levels. Testing this potential would demonstrate a physical link between stream biota and stormwater management aimed at ecological restoration.

Originality of this work

Urbanization has profound impacts on channel morphology and habitat availability. Vietz et al. (2014) recently showed that the percentage of a catchment made up of directly connected impervious areas was a strong predictor of bedload sediment depth, channel incision, bank instability, the presence of bars and benches, and large woody debris. They suggested that avoiding or undoing such impacts required a catchment-scale approach, with the aim of returning catchment hydrology towards its pre-development state. However, little is known about the realistic potential for the application of SCMs to achieve such goals. Our aim here is to firstly quantify the resultant bed shear stress values of high-flow events in a peri-urban catchment and relate these to drift losses of sensitive macroinvertebrates. Our second aim is to test the potential of stormwater source-control measures to impact high-flow hydrology and consequent bed shear stress.

Data and / or method

Our study catchment is a 4.5 km^2 peri-urban catchment to the east of Melbourne, Australia (Little Stringybark Creek). Total imperviousness in the catchment is 13% and the majority of impervious

surfaces drain directly to the stream via a conventional stormwater sewer network. The catchment is currently the subject of an ambitious attempt at the catchment-scale application of stormwater source-control measures (Walsh et al. 2015). Since Sep-2009, streamflow has been gauged in the outlet of the stream as well as in its three tributaries.

We firstly built a rainfall-runoff model of the catchment using the MUSIC software (eWater 2009). This hydrologic model included stormwater source-control measures based on the current level of intervention. The model was calibrated to observed streamflow data. We then generated a synthetic time-series of 6-min rainfall which included a range of design storm events (e.g. 1 year Average Recurrence Interval [ARI], 30-min duration), interspersed by 15 months of real rainfall data, to ensure that the storage dynamics of soil moisture and stormwater-control measures were realistically represented. This time-series of large rainfall events became input to two different adaptations of our hydrologic model. One adaptation was the catchment under pre-intervention conditions ("urban") and the other was the catchment with universal but realistic application of stormwater source-control measures ("urban + SCMs"). Both models were run and we extracted predicted 6-min flow data at various drainage points in the catchment.

The predicted high-flow hydrology at the drainage points became in turn source discharge forcing the 2D hydrodynamic model BreZo (University of California, Irvine), which had been previously adopted to model flows in the study catchment (Burns et al., 2015). BreZo was executed using an unstructured mesh of triangular elements, with variable cell resolution inside the channel of 0.25-0.5 m. Channel geometries were derived from a stream conditioned 1 m resolution lidar digital terrain model (DTM), which was processed by stream burning according to a set of RTK-GPS surveyed stream profiles. Model outputs consisted of maximum shear stress values as predicted for each cell of the model, and were compared to empirical thresholds of drift losses of sensitive macroinvertebrates.

Main results

We found that under pre-intervention conditions—i.e. no application of SCMs—there were many locations in the catchment where maximum bed shear stress was predicted to exceed levels such that 1) a wide range of sediments would be mobilized (up to course gravels), and 2) many macroinvertebrates would be lost downstream. For example, along a mid-reach of the stream, predicted maximum bed shear stress was ~30 N/m^2—large enough to cause substantial drift in sensitive macroinvertebrate taxa such as Ephemerophtera (Gibbins et al. 2010). Application of stormwater source-control measures had a moderate impact on high-flow hydrology, resulting in ~10-30% reductions in maximum bed shear stress. Such levels of bed shear stress were still higher than ecologically relevant values.

Discussion

In showing that bed shear stress in the urban context can exceed ecologically relevant values, we demonstrate a physical link between a central stream stressor and stream degradation. Our results highlight the modest potential of using SCMs to impact high-flow hydrology in ways which reduce bed shear stress. We suggest that this potential will be greater for smaller, more frequent rain events. The results provide insights for the design of SCMs to yield further reductions in benthic shear stress.

References

Burns, M. J., T. D. Fletcher, C. J. Walsh, A. R. Ladson and B. E. Hatt (2012). "Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform." Landscape and Urban Planning **105**(3): 230-240.

eWater (2009). MUSIC - Model for Urban Stormwater Improvement Conceptualisation - User Guide 4. Canberra, Australia. Available at: http://www.toolkit.net.au/Tools/MUSIC, eWater Cooperative Research Centre.

Gibbins, C., R. J. Batalla and D. Vericat (2010). "Invertebrate drift and benthic exhaustion during disturbance: Response of mayflies (Ephemeroptera) to increasing shear stress and river-bed instability." River Research and Applications **26**(4): 499-511.

Vietz, G. J., M. J. Sammonds, C. J. Walsh, T. D. Fletcher, I. D. Rutherfurd and M. J. Stewardson (2014). "Ecologically relevant geomorphic attributes of streams are impaired by even low levels of watershed effective imperviousness." Geomorphology **206**(0): 67-78.

Walsh, C. J., T. D. Fletcher, D. G. Bos and S. J. Imberger (2015). "Restoring a stream through retention of urban stormwater runoff: a catchment-scale experiement in a social-ecological system." Freshwater Science **34**.

Walsh, C. J., A. H. Roy, J. W. Feminella, P. D. Cottingham, P. M. Groffman and R. P. Morgan (2005). "The urban stream syndrome: current knowledge and the search for a cure." Journal of the North American Benthological Society **24**(3): 706-723.

VALUATING THE ABILITY OF A STATISTICAL MULTIVARIATE ANALYSIS TO REPLICATE RELEVANT ECO-HYDROLOGICAL INDICATORS

Ersilia D'Ambrosio, Environmental and Infrastructure Engineering, Polytechnic University of Milan, ersilia.dambrosio@polimi.it

Anna Maria De Girolamo, CNR-IRSA, Bari

Maria Cristina Rulli, Environmental and Infrastructure Engineering, Polytechnic University of Milan

Key words (5 at the most)

(2.5, 2.7) Mediterranean river, Flow regime, Hydrological Indices, Principal Component Analysis, Regression Analysis

Topic of this work

The structure and composition of aquatic biota in temporary stream are strongly dependent on the temporal changes of the aquatic habitats determined by the hydrological conditions. The Water Framework Directive requires the evaluation of the ecological status (ES) by means of biological samplings. This could be a difficult task for temporary stream, which aquatic life and mesohabitat composition depend on flow availability. Thus before evaluating ES, hydrological conditions should be adequately characterized.

Research question (or operational application)

This paper presents a study carried out to analyze hydrological regime in a Mediterranean basin. It computes 36 Hydrological Indices using a long-term flow records from 10 gauging stations located in South Italy. Among these indices a set of non-redundant indices was identified, which describe the main critical characteristics of regime in the study area. Selected significant indices were linked to catchment characteristics fitting statistical relationships in order to use them in ungauged river segments.

Originality of this work

The main goal of the present work was to provide to ecologists and water resources managers an easy tool for classifying streamflow regime when streamflow data are not available. A multitude of different way exists in which hydrological regimes and their degree of alteration can be characterized: a large number of Hydrological Indices (HIs) have been developed. These indices are based on monthly or daily streamflow measured time series. Stream ecologists have to face the difficult task of choosing from a plethora of available HIs a minimum subset, which adequately describe the main aspects of the flow regime and ecological function hence. In the present paper, we tested a methodology for analysing and classifying hydrological regime in a Mediterranean basin with a temporary river network. In a first step, we identified a set of non-redundant HIs which describe the main characteristics of hydrological regime in small temporary catchments. Two metrics were selected and

used for classifying the river reaches. Then, we tried to evaluate the ability of a statistical multivariate analysis to replicate metrics and flow regime classification without using streamflow data.

Data and / or method

The study area are the Candelaro, Carapelle and Cervaro river basins (Puglia, Southern Italy). These basins have typical Mediterranean semi-arid features, characterized by flash floods and drought period.

Using daily flow records (1965-1996) from 10 gauging stations, 36 HIs were examined. The IHA software was used for calculate 33 indices, using not parametric statistics. Three additional indices were evaluated by using spreadsheets. Before compare results a normalization procedure was performed because some parameters depend on the subbasin area. A Principal Component Analysis was performed to identify subsets of HIs that describe the major aspects of regime while minimizing redundancy. Finally, the relationship between the significant HIs and basin characteristics (stations elevation, basins area, forests coverage, mean annual precipitation (1967-1996), mean soil permeability and soil available water content) was found by using a stepwise multiple regression analysis (SMRA) applied on 7 stations. Before applying SMRA all dependent and independent variables were log(x+1) transformed. The model was validated on the remaining 3 stations.

Main results

The authors report that temporary streams are mainly described by magnitude and duration of annual extreme water conditions and by rate and frequency of water condition changes. We identified 8 significant indices. Multiple regression analysis was applied on these significant HIs. Two indices were selected and used for classifying the river reaches: SD6 and MF. These indices, which were calculated by using streamflow data and by using catchment characteristics, were compared.

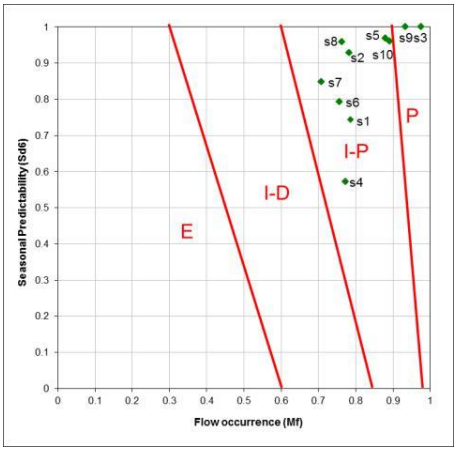


Fig.1: SD6, MF derived from flow data characteristics

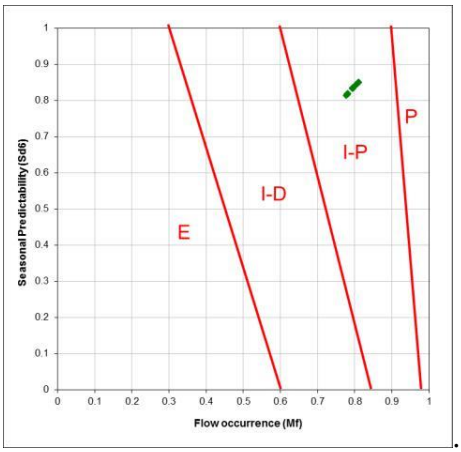


Fig. 2: SD6, MF predicted using catchment

Most stations fell into the same groups using catchment characteristics (Fig.2) as in the graph based on long-term flow data (Fig.1). However, in the new classification s3 and s9 were assigned to different flow regime groups than in the flow based analysis, shifting from permanent (P) to Intermittent-Pools (I-P) regime. In fact, the natural flow of s3 and s9 reaches has been altered because of wastewater treatment plant discharges that make their regime permanent.

Conclusion / Perspectives

This study identifies the most relevant eco-hydrological indices in temporary rivers and provides a tool for determine these indicators in ungauged streams. Indices, obtained by using catchment characteristics, can be useful to classify river reaches and to roughly assess flow regime alterations for ungauged catchments. Using SD6 and MF metrics it's possible to derive generalizations and information which are useful for ecologists in differentiate the river types as needed by the Water Framework Directive (2000/60/EC).

NOVEL RIVER ECO-HYDROLOGICAL SYSTEMS PROJECTED FOR EUROPE

Dr Cédric Laizé, Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, OX10 8BB, UK, clai@ceh.ac.uk

Prof Mike Acreman, Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, OX10 8BB, UK, man@ceh.ac.uk

Dr Ian Overton, CSIRO, Land and Water, PMB 2 Glen Osmond SA 5064, Australia, ian.overton@csiro.au

Key words (5 at the most) *river ecosystem; flow alteration; eco-hydrological region; climate change; Europe*

Topic of this work Future flows in rivers throughout Europe were computed for different combinations of climate models and socio-economic scenarios for a baseline (1961-1990) and for the future (2050s). Sets of indicators describing all ecologically-relevant facets of river flow regime were derived. Eco-hydrological regime types were defined using classification techniques applied to these indicators. Projected future flow alterations (2050s) for major European rivers were mapped in terms of eco-hydrological types and compared with maps for the baseline situation. It was found that for many river reaches their regime would remain broadly similar (in the same class), for other reaches the regime would alter to be more similar to another class. For some reaches the eco-hydrological regime would change to a novel form not currently seen in Europe, with the potential to create new river ecosystems.

Research question (or operational application) It is widely acknowledged that changing hydro-climatological conditions associated with changing socio-economics will impact the global hydrological cycle with implications for human use of water resources and for aquatic ecosystems and the services they provide to mankind. Studies like the Millennium Ecosystem Assessment show that many water-dependent ecosystems are being degraded or lost. River restoration requires reference conditions to set-up appropriate outcome targets, which traditionally relate to past ecological state. However, under changing water availability, whether due to water use or climate, reverting to such reference conditions may be too restrictive as it does not take into account the natural variability of the system, nor its evolution. The study aims to identify baseline river ecosystem types and to assess how they may evolve in the context of changing climate and socio-economic conditions across Europe. In turn, this could contribute to identifying appropriate target conditions.

Originality of this work There are few studies addressing future ecologically relevant flow regimes and most focus on a limited number of sites and/or a limited geographical extent, and are often descriptive rather than quantitative. This study is one of the few: (i) to provide pan-European geographical coverage, (ii) to use a detailed (given the geographical extent) river network based on 33,368 cells with a 5' x 5' resolution, (iii) to consider explicitly a set of ecologically-relevant hydrological indicators (i.e. all facets of the flow regime), and (iv) to consider not just climate-induced change, but combined climate and socio-economic pressures.

Data and / or method Eleven sets of modelled monthly flow series were generated using different combinations of climate data inputs and socio-economic scenarios by running the continental-scale water model WaterGAP 3.1 (Water – Global Assessment and Prognosis; University of Kassel; 5' x 5' grid). Climate inputs included observed historical climate data (1961-1990) and projected future climate data for 2040-2069 ('2050s') from two GCMs, IPSL-CM4 ('IPCM4') and MIROC3.2 ('MIMR'). Model runs were as follows: Baseline, historical naturalised flows (i.e. no water usage) for 1961-1990; five model runs for each GCM representing future flows under various water usage conditions (naturalised flows ('Natural') and four socio-economic scenarios representing extreme possible future for the pan-European area). A subset of the WaterGAP cells was selected

corresponding to all major European rivers and their tributaries thus totalling 33,368 cells. Monthly flow statistics, thereafter referred to as Monthly Flow Regime Indicators (MFRIs), were derived for all 11 modelled flow series. They include 14 metrics capturing all aspects of the flow regime: timing, magnitude, frequency of extremes, etc. For each model run independently, all cells (i.e. 33,368) were grouped based on similarity of MFRIs using cluster analysis (CA). CA was done in two stages: hierarchical clustering followed by non-hierarchical clustering (k-means). Each identified class represents a hydrological type, the specific set of ecologically significant flow metrics of which is assumed to represent an ecological type, therefore referring to the class as an eco-hydrological type.

Main results Five classes were identified for the Baseline, seven for both IPCM4 and MIMR 2050s runs. Each cell was colour-coded according to its river type derived from CA, then mapped (Figure 1 shows the river types for the Baseline and for IPCM4 2050s). The number of cells changing river types from Baseline to 2050s runs are as follows: (i) a majority of cells do not change river type (c. 55% for IPCM4 and c. 60% for MIMR); (ii) some cells shift to an existing Baseline river type (c. 15% for both IPCM4 and MIMR); (iii) some cells shift to a new river type (c. 30% for IPCM4 and c. 20% for MIMR). The broad patterns in term of class shifts are: most of northern Europe and northern Africa is unchanged; there is a roughly southwest-northeast-southeast belt (including Spain, France, south of the UK, etc.) where rivers change to a novel eco-hydrological type; the remainder changes to an existing river type (for example, class 5 expands in Norway).

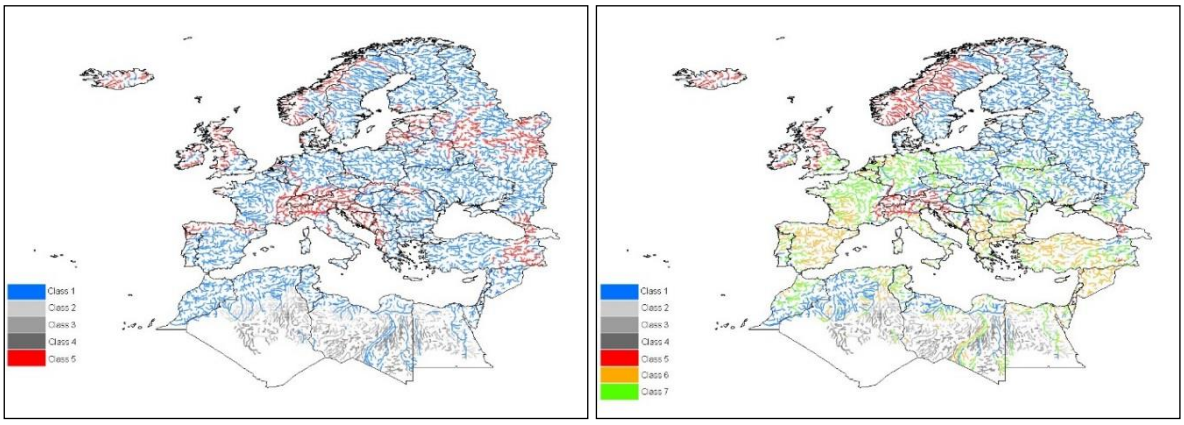


Figure 1 Left, Baseline k-means 5 classes; Right, IPCM4 Natural 2050s k-means 7 classes

Discussion The implications of changing from one eco-hydrological type to another may differ depending on species or ecosystem services being considered, or on which aspect of the flow regime is changing (e.g. lower flow variability benefits macrophytes but higher magnitudes may be detrimental). For rivers changing toward an existing type, their ecology may change to reflect that type, although there are other controls beside hydrology that need to be considered (e.g. water temperature, water quality). Further research is on-going to relate the current and future eco-hydrological typology to observed biological data (e.g. broad-scale fish species richness). The findings provide guidance for setting appropriate flow targets for restoration and conservation under the Water Framework Directive.

ECOSYSTEM IMPACTS OF ALPINE WATER INTAKES – THE KEY ISSUE OF THE SEDIMENT MANAGEMENT

Gabbud Chrystelle and Lane Stuart N, Institute of Earth Surface Dynamics (IDYST), University of Lausanne, chrystelle.gabbud@unil.ch, stuart.lane@unil.ch

Key words: water intake, hydroelectric production, sediment management, sediment purges, ecological impacts *(Topic 2)*

Topic of this work

Natural Alpine flow regimes may be strongly modified by hydroelectric production, which impacts upon both river discharge and sediment transfer systems, and in turn downstream flora and fauna. The ecological impacts of rivers regulated by barrages, with sediments retained behind walls, are well studied. By contrast, there has been much less focus on water intakes (Figure 1). Like barrages, such intakes also trap sediment, but because they are much smaller, they fill more frequently and so need to be flushed regularly in purges. Downstream, such purges feed the river with solid material, whilst the transport capacity is drastically diminished which leads to downstream aggradation. Subsequent purges may remobilise this material but the duration of remobilisation is commonly much shorter than the duration under natural flows. Hence, the aggrading zone migrates downstream, as a wave of sediment propagating through time. It induces a continuous channel morphological response, modifying refugia, spatial structure and habitats, resulting in a diversity and productivity decline. The ecosystem impacts of such systems have been rarely considered. Indeed, whilst the effects of flow abstraction on ecology may be reduced through a compensation release, this does not deal with the problem of sediment which may only be transported at higher flows.

Figure 1: a classic Alpine water intake (Lower Berthol, Valais, Switzerland)

Research question (or operational application)

The first aim of this study is to establish a synthesis of what we know about the hydrology, geomorphology and aquatic ecology of natural Alpine streams. The second one it to describe how flow abstraction through intakes may impact upon Alpine sediment transfer and stream ecology and to outline the key research questions that will need to be addressed in order to modify intake management so as to reduce downstream ecological impacts.

Originality of this work

At present, the management of sediment is rarely considered in legislation designed to improve such flow abstraction systems, which commonly only imposes conditions relating to flow hydrological characteristics (such as magnitude, frequency, duration, timing and rate of change) (Poff et al., 1997). This is not surprising as there are almost no experiments, and hence scientific bases, that might be used to define the kinds of instream flow needs necessary to manage sediment and to secure an improved river ecology. This study attempts to fill this lack of knowledge giving an overview of the problems related to the water intakes. Furthermore, we are involved in forthcoming flow trials with Alpiq and HYDRO Exploitation SA in the Borgne d'Arolla (Valais, Switzerland), a gravel-bed Alpine stream. Excluded from the Swiss Water Law (LEaux, 1991), the intakes are currently testing possible low flow releases (between 60 % and 100 % of Q_{347}) of water, which will give us the chance to identify in-situ eco-geomorphological responses of the river.

Data and / or method

The synthesis of the hydrology, geomorphology and aquatic ecology of natural Alpine streams is extracted from the literature according to the submitted paper Gabbud and Lane, in review. Archival image analysis has been used to construct digital elevation models of the Borgne d'Arolla dating back to the 1950s, and this has allowed us to identify the history of sedimentation following from flow abstraction and relate this to river flow records, including changing purge frequency. We are currently monitoring the Borgne d'Arolla during a suite of flow trials using ground-based laser scanning (LiDAR), drone monitoring, sediment sampling and ecological sampling. Preliminary results will be presented and first assumptions and lessons will be discussed.

Main results

The key point from the discussion around the ecological impacts of water intakes is that, unlike barrages, they do not eliminate sediment connectivity, rather they reduce its intensity, having profound hydrogeomorphic impacts. The system impact is progressive sedimentation, widening the active channel width and leading to loss of floodplain habitat. We demonstrate severe loss of habitat arising from these changes as well as negative impacts upon instream flora and fauna. The analysis of changes in sediment transport capacity shows that the non-linear and threshold dominated nature of sediment transport in a gravel-bed river system means that reintroducing minimum flows has no impact on this sedimentation. Reintroducing high flows is not logical as these are already produced during purges. The solutions that need to be considered are likely to be more adaptive, involving finding ways of living with the 'legacy sediment' produced by the effects of flow abstraction.

Conclusion & Perspectives

The wider importance of this paper is that it looks at a much overlooked element of the Alpine water management system from the perspective of sediment. Much research has addressed the need for minimum instream flows but has not considered how sediment should be factored into such a consideration.

Acknowledgements

This study would not have been possible without the support of the Swiss National Science Foundation (SNSF) through the NFP70 Project «Optimizing environmental flow releases under future hydropower operation» (HydroEnv) and the University of Lausanne (UNIL)

References

Gabbud, C., Lane, S.N., in review. Ecosystem impacts of Alpine water intakes: the key issue of the sediment management. Submitted to WIREs Water.

Poff, N.L.R., Allan, J.D., Bain, M.B., Karr, J.R., Prestergaard, K.L., Richter, B.D., Sparks, R.E., Stromberg, J.C., 1997. The Natural Flow Regime - a paradigm for river conservation and restoration. BioScience, 47, 769-784.

QUANTIFYING EFFECTS OF FLOW REGULATION ON RIVER HABITAT BY 2D HYDRODYNAMIC MODELLING

Peter Molnar, ETH Zurich, Institute of Environmental Engineering, 8093 Zurich, Switzerland, molnar@ifu.baug.ethz.ch
Paolo Perona, EPF Lausanne, Applied Hydroeconomics and Alpine Environmental Dynamics, 1015 Lausanne, Switzerland
Paolo Burlando, ETH Zurich, Institute of Environmental Engineering, 8093 Zurich, Switzerland

Key words : hydrodynamic modeling; river habitat analysis; environmental flows (2.7); Maggia River (2.5)

Topic of this work

The presentation will illustrate an assessment method to quantify effects of flow regulation on morphological habitat in a braided gravel bed Alpine river in southern Switzerland (Maggia). The method combines a simplified hydropower system model, 2d hydrodynamic modeling of the affected braided river reach, and the derived distribution approach to quantify changes in the extent of river morphological habitat for pre- and post-dam conditions and different environmental flow (release) levels.

Research question (or operational application)

The research objective is to use 2d hydrodynamic modeling to objectively quantify river morphological habitat, i.e. extent of pool and riffle aquatic habitat, without extensive calibration and field measurements. The operational aspect is that the presented methodology can be used to quantify the ecological benefits of different environmental flows and associated economic losses by decreased hydropower production, and thereby aid in the analysis of optimal flow release strategies.

Originality of this work

This work is original in the combination of three elements: hydropower system modeling, 2d hydrodynamic modeling, and time series analysis of habitat-related variables. Many studies use flow indexes to quantify flow regulation effects in a lumped fashion, e.g. indexes of hydrological alteration and ecodeficit (e.g. Richter et al., 1996; Gao et al., 2009), while we use direct simulations of flow depth and velocity to estimate spatially resolved river morphological habitat and estimate its areal and temporal extent. This gives us a versatile, hydrodynamic-based methodology, which can be combined with other new approaches to quantify how riparian benefits relate to hydropower benefits (e.g. Perona et al., 2013).

Data and/or method

The data used are pre- and post-dam periods of over 20 yrs of daily streamflow records in the Maggia River. The construction and operation of the hydropower system in the basin has led to a 75% drop in mean flow (Molnar et al., 2008). This potentially determined significant negative effects on riverine ecosystems (Nilsson and Berggren, 2000). For the modeling of the braided river reach we use a high

resolution (LIDAR) digital elevation model, with aerial photographs used for the validation of the inundated area. River bed sediment size distribution was derived from field point surveys.

The analysis methods consist of three elements: (1) a simplified hydropower system model which computes the releases of the headwater system into the Maggia River as a function of hydrological inputs and reservoir/intake capacities; (2) a 2d hydrodynamic model (BASEMENT) of the affected braided river downstream from which flow depth, velocity and morphological indexes are computed; and (3) the derived distribution approach to estimate the morphological index for pre- and post-dam conditions.

Main results

First, the conceptual spatially lumped hydropower model was calibrated with pre-dam streamflow data and current environmental (minimum) flow releases to reproduce the post-dam statistical distribution of daily streamflow. A range of pre- and post-dam streamflow (low and high flows) was selected and steady state runs with BASEMENT were simulated for a 5km long reach. Flow velocity v and depth h were used to derive a morphological index defined as the ratio of normalized v/h. The reach was classified into pool and riffle morphologies with different habitat quality. An example for low flow is shown in Figure 1.

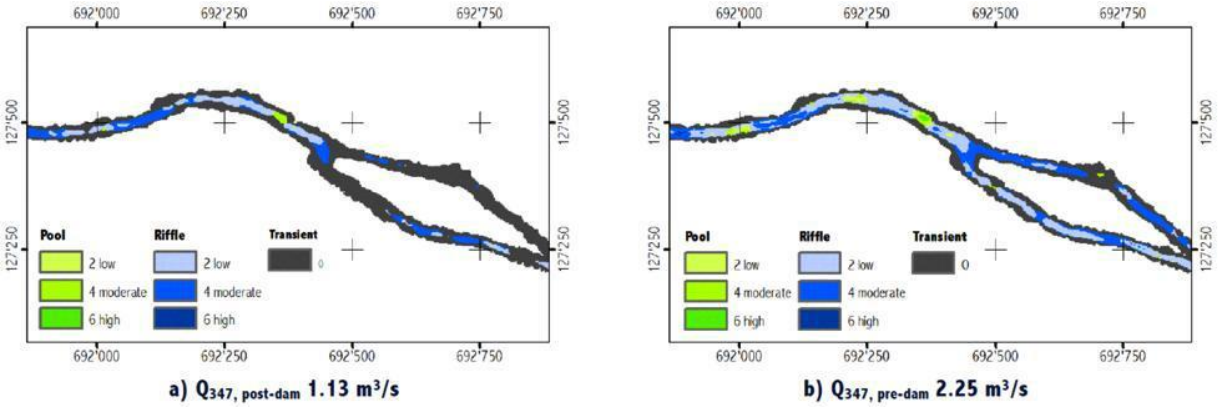


Figure 1: River morphological habitat (pools, riffles, transitional) for (a) post-dam and (b) pre-dam low flow (Q_{347}) conditions. Habitat quality is classified into three classes (low, moderate, high).

Second, the habitat index values for each steady state flow Q were integrated over pre- and post-dam probability distributions f(Q), and it was shown that the overall habitat dropped markedly due to the disappearance of riffle morphologies, while pool habitat remained stable. The statistics of habitat change were evaluated jointly with potential energy production for a range of environmental flow releases.

References

Gao, Y., Vogel, R.M., Kroll, C.N., LeRoy Poff, N., Olden, J.D. (2009). Development of representative indicators of hydrologic alteration. J. Hydrol. 374, 136-147.

Molnar, P., Favre, V., Perona, P., Burlando, P., Randin, C., and Ruf, W. (2008) Floodplain forest dynamics in a hydrologically altered mountain river, Peckiana, 5, 17–24.

Nilsson, C., and Berggren, K. (2000) Alterations of riparian ecosystems caused by river regulation, BioScience, 50, 783–792.

Perona, P., Dürrenmatt, D.J., and Characklis, G.W. (2013) Obtaining natural-like flow releases in diverted river reaches from simple riparian benefit economic models, J. Env. Management, 118, 161-169.

Richter, B.D., Baumgartner, J.V., Powell, J., and Braun, D.P. (1996) A method for assessing hydrologic alteration within ecosystems, Conserv. Biol., 10, 1163-1174.

OPTIMIZATION OF CONSERVATION PRACTICE IMPLEMENTATION STRATEGIES IN THE CONTEXT OF ENVIROMENTAL FLOW

A. Pouyan Nejadhashemi, Michigan State University, pouyan@msu.edu Matthew R. Herman, Michigan State University, hermanm7msu.edu@gmail.com Fariborz Daneshvar, Michigan State University, fariborz@msu.edu

Dennis M. Ross, Michigan State University, rossdenn@msu.edu Sean A. Woznicki, Michigan State University, woznicki@msu.edu Zhen Zhang, University of Chicago, zhangz19@galton.uchicago.edu Abdol-Hossein Esfahanian, Michigan State University, esfahani@msu.edu

Key words (5 at the most) Variable Selection; Biological Integrity; Soil and Water Assessment Tool; Hydrologic Index Tool; Genetic Algorithm

*(*2.6 Aquatic communities to evaluate environmental flows relevance*)*

Topic of this work

This study aims to improve stream health by optimizing agricultural best management practice (BMP) implementation at the lowest possible cost. Stream health models were developed using adaptive neuro-fuzzy inference systems (ANFIS) and the Soil and Water Assessment Tool hydrological model. Watershed-scale management strategies were optimized using a genetic algorithm that implemented alternative scenarios of five agricultural BMPs. The resulting maximized fish Index of Biotic Integrity (IBI) and minimized cost of implementation were the optimization criteria. Eight unique BMP implementation scenarios were identified that produced watershed-scale IBI scores of "excellent" for the Honeyoey Cree-Pine Creek watershed in Michigan. Here, the no-tillage BMP was most often implemented across the watershed, indicating its effectiveness in improving stream health at low cost. This modeling process can be adapted regionally to develop watershed management solutions that consider both environmental and economic impact.

Research question (or operational application)

The concept of environmental flows was founded on the concept of maintaining minimum levels water to sustain an ecosystem. This concept has expanded in scope to include replication of natural flow cycles based on timing and volume. Using the updated environmental flows concept in tandem with stream health indicators, watershed managers can identify degraded streams from a biological perspective and develop implementation plans that focus on ecosystem restoration and protection. However, there are two challenges in implementing this concept in large and diverse watersheds: (1) widespread biological monitoring of all streams in a watershed is expensive and impractical, and (2) exhaustive exploration of all potential watershed management alternatives is resource intensive and effectively impossible.

Originality of this work

Modeling provides an avenue to address these challenges through effective and inexpensive methods for exploring both watershed-scale stream health conditions and management alternatives to improve or maintain these conditions. However, research is scarce in the context of optimizing agricultural BMPs to address stream health, which is the goal of this study. To address this goal, the specific objectives were to: (1) extend stream health predictions as represented by a biological indicator beyond monitoring points, and (2) develop several watershed-scale management alternatives that are optimized based on maximizing stream health and minimizing implementation cost.

Data and / or method

This study consisted of two phases: stream health model development (performed in the Saginaw Bay Watershed of Michigan) and the scenario phase (performed in the Honeyoey Creek-Pine Creek Watershed of Michigan). In the development phase, several objectives were completed to create a model of stream health as represented by the fish IBI. First calibration and validation of a Soil and Water Assessment Tool (SWAT) model was performed to obtain daily time-series streamflow for all stream segments in the Saginaw Bay Watershed. This data was input into the Hydrologic Index Tool (HIT) to calculate 171 environmental flow indices. Given the cumbersome number of potential predictor variables, a Bayesian variable selection method was employed to identify important flow indices with respect to IBI. Using these variables, ANFIS models, a fusion of fuzzy logic and artificial neural networks, were developed to predict stream health at all stream segments.

The scenario phase integrated the stream health model into a genetic algorithm (GA). The GA explored several alternative watershed-scale BMP implantation scenarios with the objective of finding a near optimum solution of minimizing implementation cost and maximizing stream health. Here, BMPs were implemented in SWAT, the resulting long-term daily streamflow was simulated, the relevant environmental flow indices were calculated and fed into the ANFIS to estimate resulting IBI at each stream segment. For each iteration, the stream-length weighted IBI for the Honeyoey Creek-Pine Creek Watershed and cost of BMP implementation were calculated. The GA used the IBI and cost to move to the next generation and the process was repeated until the objectives (a near optimum solution) were achieved.

Main results

A near optimum solution of watershed-scale BMP implementation was obtained through maximizing stream health and minimizing implementation cost. Here, eight unique alternatives of BMP implementation were identified that achieved a maximum watershed-scale stream health (IBI) score of 71. To achieve this score, no-tillage was the most commonly implemented BMP.

Discussion

This study can provide valuable information to decision-makers through development of watershed-scale BMP implementation plans that are tailored to achieve maximum stream health while addressing their cost-related concerns of implementation.

DESIGNING NEW WATER MANAGEMENT SCENARIOS IN ALTO VINALOPO SEMIARID LANDSCAPES (SE. SPAIN). INTEGRATING ECOLOGICAL THRESHOLDS, WATER DEMANDS AND ENVIRONMENTAL IMPACTS

Antonio Pastor-Lopez, Dep. of Ecology / IMEM-MIES (Multidisciplinary Institute for Environmental Studies – Ramon Margalef),
University of Alicante Ap.99 Alicante

E- 03080 SPAIN,
Antonio.Pastor@ua.es
Jose Antonio Perez-Lahiguera, Dep. of Ecology, University of Alicante.

Jose Emilio Martinez-Perez, Environmental CartographyLab, University of Alicante .

Key words : (Water uses, Landscape management, Water Framework Directive (WFD), Ecohydrology, Spatial ecology)

(2.5, 2.7, 2.4, 2.3, 3.2)

Topic of this work

Topic 2: Methods and models for the determination of environmental flows in rivers and estuaries.

Research question (or operational application)

Are environmental flows a relevant management tool in high water demand heterogenous agroecosystems in semiarid mediterranean landscapes with intermittent or artificial flow rivers. New Land-use models for South Eastern Spain.

Originality of this work

Since the beginning of the XX century, Vinalopó river and its tributaries (Alicante province) had suffered a great reduction in their water regimes. This situation was mainly caused by aquifers overexploitation for both irrigation and human consumption outside the catchment. As a consequence, Alto Vinalopó county is a clear example of unsustainable development in relation to water exploitation. The situation reached a critical point, ecologically speaking, when water for irrigation was substantially diminished due to the new dripping systems.

This contribution described the main environmental factors driving this degradation scenario in order to identify the main clues to slow it or stop it down in the short term. This analysis represented a new management approach to a common reality in complex semiarid mediterranean

lowland agroecosystems. Due to the initial restrictions in water availability, the natural flow paradigm was not considered a realistic answer, due to water demands conflicts and spatial scaling problems. New approaches were suggested with more effective and efficient artificial water inputs. In order to reach this goal, spatial data was obtained to identify the appropiate magnitude for the relevant state variables.

Data and / or method

The data obtained was mainly extracted from aerial photos analysis and landscape surveying using GIS programs (ARCINFO and IDRISI), as the representation, analytical and spatial modelling tool. Given the limited access to sound information on water availability, the first approach was directed to those related landscape features showing fragmentation and degradation. The changes in the old irrigation network in a representative area from the "Huerta y Laguna de Villena" was the center of the study. New water inputs and outputs together with the qualitative info for relevant biodiversity sites was used in the discussion.

Main results

In a first approach, the results showed a broad picture of the ecological evolution of the upper sector of Vinalopó river under the main water demand scenarios. The different river types present appeared as a consequence of management history, water demands evolution and environmental characteristics of the river bed and banks. The main changes in the ecological status of both the freshwater, riparian and associated wetlands were presented.

For the "Huerta y Laguna de Villena" the main old irrigation network characteristics and its changes were quantified. The remainning natural, artificial (good and bad quality) water imputs were drawn for a qualitative and semiquantitative description of the past and present scenarios.

Conclusion

Finally for this same area, different environmental flow scenarios were discussed from the zero depurated water input (suggested by the irrigation communities stakeholders) , to 10 per cent of the daily depurated water (around 900 cubic meters per day suggested by the Hydrological Authority (Confederación Hidrográfica del Jucar). The feasibility to reach the natural flow paradigm status on the "Acequia del Rey" the only Vinalopó river tributary, in the area, that keeps a permanent water regime on mainly artificial inputs was also evaluated. Special attention was paid to the potential for restoration or reallocation of sites for *Aphanius iberus* local populations to be reintroduced. As well as the potential for other relevant freshwater species. The new land use management scenarios were considered after gathering the feedback from the local authorities in a panel session with them. The potential for reaching scenarios to given several uses (services) for the same volume of water was discussed under these specific circumstances.

Acknowledgements

Part of the data used for the landscape features and irrigation networks description was funded by the M.I. Ayuntamiento de Villena under the contract " Diagnóstico y catálogo de la red de enclaves hidrológicos y construcciones hidraúlicas ecológicamente relevantes para mantener, conservar y potenciar el Patrimonio Natural del término municipal de Villena. Zona I ". Part of the information

used for the water demand and stakeholders description and analysis was conducted within the WADI Project (INCO2003-MPC2-015226) and financed by the European Commission.

ESTIMATING ENVIRONMENTAL FLOWS (EFLOWS) IN POLAND

Piotr Parasiewicz[1,2], Paweł Prus[1], Katarzyna Suska[3]

[1]S. Sakowicz Inland Fisheries Institute, Oczapowskiego 10, 10-719 Olsztyn, Poland
[2] Rushing Rivers Poland, Rozwojowa 79, 05-300 Mińsk Maz.
[3] Warsaw University of Life Sciences, Nowoursynowska 166, 02-787 Warszawa

Key words: environmental flows; MesoHABSIM, fish community, river classification

The purpose of this project is to define and describe the concept of "environmental flows" and to identify the most adequate methods for eflows estimation in Poland. These considerations took into account the specifics of environmental conditions, the availability and reliability of the data as well as the requirements of the Water Framework Directive and the European Commission regarding eflows. The literature review is followed by development of an overall concept and a test pilot investigation, during which the assumptions have been tested. For the pilot project phase we proposed utilization of two types of methodologies:

• Hydrological methodology (desktop) - for morphologically unaltered water bodies;
• Habitats simulation methodology - for modified, heavily modified and artificial water bodies.

The limitation of hydrologic desktop methods is to identify flow thresholds reflecting the variability of habitat conditions. Hence the thresholds are determined with help of MesoHABSIM model developed for 6 Target Fish Guilds Communities typical for Polish rivers and habitat time series analysis. The result are river type specific seasonal value of subsistence, base, high pulse, and overbank flows, together with their frequencies and durations.

"SNAPSHOT" CHARACTERIZATION OF INDUSTRIAL RIVERS

Marie-Noëlle Pons 1, @ , Aziz Assaad, @
1 : Laboratoire Réactions et Génie des Procédés (LRGP)
CNRS : UMR7274, Université de Lorraine
LRGP ENSIC CNRS B.P. 20451 54001 Nancy Cedex - France

"SNAPSHOT " CHARACTERISATION OF INDUSTRIAL RIVERS

Aziz Assaad, M.N. Pons

Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine,
1 rue Grandville, BP 20451, 54001, Nancy cedex, France

Introduction

During the XIXth century, in the Northern region of France as well as in Belgium, Luxembourg or Germany, large industrial activities were developed based on coal and iron mines and steel milling. The mines are now closed in France and steel industry has been declining for the last thirty years leading to the existence of many brownfield sites. Even during the golden ages of these industrial activities, protection of the aquatic environment was not a key issue and many rivers still bear scars of this behavior. In Lorraine, some of these rivers are tributaries of the Moselle River (Fensch River, Orne River, etc.). Their water and sediments are often polluted by PAHs and heavy metals. Furthermore the rivers received still now badly treated (or untreated) industrial and domestic effluents as well as run-off from brownfields. "Snapshot" campaigns enable to have a close look to the pollution sources along a watercourse as the distance between sampling stations is short. This methodology has been used to compare two industrial rivers: the Orne River (which restoration started in 1970) and the Fensch River.

Study area : Two rivers were studied (figure1): the Orne River which is a left tributary of the Moselle and sub-tributary of the Rhine and it drains a catchment of 1268 km². Its source is in the hills northeast of Verdun. It flows east and joins the Moselle near Mondelange, between Metz and Thionville after a course of 85.8 km. The Fensch River is also a left tributary of the Moselle River and it drains a catchment of 82.8 km². It has its source in Fontoy, and joins the Moselle River in Illange after a course of 13.5 km.

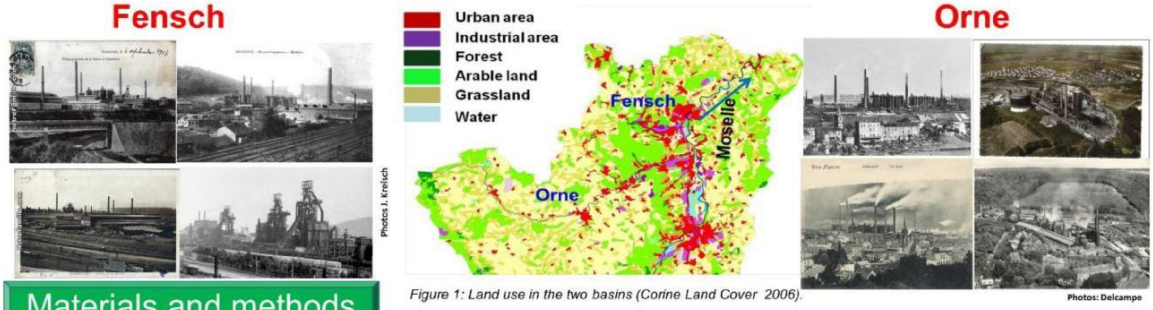


Figure 1: Land use in the two basins (Corine Land Cover 2006).

Materials and methods

Samples have been collected from road and foot bridges (when easily reachable) along the Fensch River, the Orne River and its main (sub)tributaries (Longeau River, Yron River and Woigot River). The samples are analyzed for their dissolved organic matter as well as mineral content (Ca, Mg, Na, K, chlorides, sulfates, ammonium and nitrates). Absorbance spectra as well as fluorescence synchronous spectra (with a 50 nm gap between excitation and emission) are collected. In terms of fluorescence, synchronous spectra are collected on a F-2500 spectrofluorometer (Hitachi) using a PMMA cuvette. Excitation varies between 230 and 600 nm. Slits of 2.5 nm are used. The photomultiplier voltage has been set at 700V. Ultra-pure water is used for blanking and the Raman water peak is used for standardization.

Fensch

Results

Orne

The spatial monitoring enables to detect the main breakpoints in terms of surface water quality. The effect of mine water discharges/run-off is clearly visible with an increase of the conductivity and of the sulfates concentrations (figure 2(a, b)) near the former mining sites.

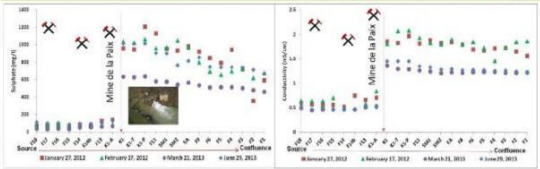


Figure 2a : Sulphate concentrations and conductivity along the Fensch river.

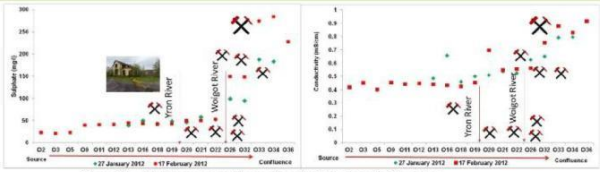


Figure 2b : Sulphate concentrations and conductivity along the Orne river.

Figure 3a shows series of synchronous spectra collected during four different sampling trips along the Fensch River between the source (Fontoy) and the junction with the Moselle River at Illange. In the spectra the closest to the source it is often possible to recognize a peak around λ_{ex} ≈280 nm which can be attributed to tryptophan-like fluorescence related to untreated domestic sewage. However peaks appear downstream which are more difficult to relate to humic substances. By comparison with (pure HAPs in ultra-pure water), it can be assumed that phenanthrene and fluoranthene can be present in the water samples. The fluorescence spectra collected along the Orne River (figure 3b) exhibit typical bands related to protein-like substances and humic-like substances. A change is the relative importance of protein-like fluorescence with respect to humic-like fluorescence is noticeable downstream of Auboué, when the industrial/urban land cover increases with respect to the more agricultural land cover observed in the upstream part of the watershed.

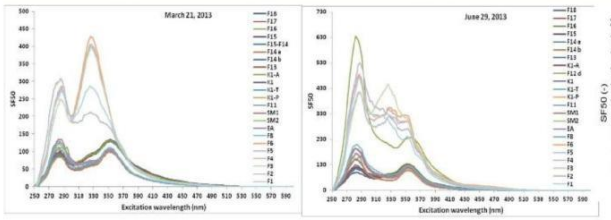


Figure 3a: Series of synchronous spectra collected at different dates along the Fensch river.

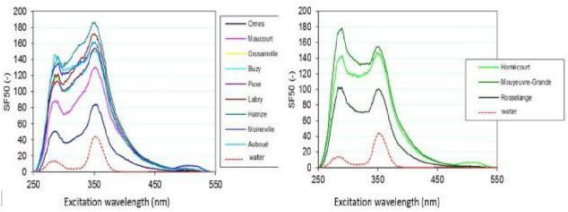


Figure 3b: Synchronous fluorescence spectra along the Orne River, from Ormes (source) to Rosselange

Conclusions

To monitor the improvement of the status of industrial rivers under restoration, sampling campaigns were organized. In addition to the traditional analysis, optical methods (UV-vis and fluorescence spectroscopy) are applied to characterize the dissolved organic matter. The "snapshot" methodology enables to have a more refined spatial monitoring of the watercourse than the Rhin-Meuse Water Board.

Acknowledgements

The authors wish to thank the Zone Atelier du Bassin de la Moselle and the Région Lorraine for their financial support

3- Social and economic values of water-related ecosystem services

HOW DOES FOREST COVER IMPACT WATER RELATED ECOSYSTEM SERVICES? IMPROVE FUNCTIONS' UNDERSTANDING FOR A BETTER SERVICES ASSESSMENT.

Brogna D., Department of Geography, University of Namur. 61 Rue de Bruxelles, 5000 Namur, Belgium ; delphine.brogna@unamur.be

Dufrêne M., Research Platform AgricultureIsLife, Unity Biodiversity and Landscapes University of Liege, Gembloux Agro-Bio Tech, Belgium; marc.dufrene@ulg.ac.be

Vincke C., Faculty of Bioscience Engineering & Earth and Life Institute, Université Catholique de Louvain, Belgium; caroline.vincke@uclouvain.be

Dendoncker N., Department of Geography, University of Namur, Belgium, nicolas.dendoncker@unamur.be

Key words: hydrological services, forests, indicators, land cover

(1)

Topic of this work

Forests provide a broad set of ecosystem services (ES), in particular related to water. They play a crucial role in supplying clean water and mitigating water damages downstream. These water-related services can be described in terms of quantity, quality and timing. The present work aims to better tackle the impact of forest cover on water related ES in terms of quantity and timing.

Research question (or operational application)

The research question addressed in this study is "h ow does land cover (LC) and in particular forest cover impact water related ES?". This study addresses thi s question in the Walloon context (Belgium) and brings information on the complexity of the links between ecosystems and services through multiple processes, with potentially antagonistic effects on functions.

Originality of this work

Although the hydrological role of forest has been documented, there is still a lack of knowledge regarding the complexity underlying the links between ecosystem functions and services. This must be revisited in the context of climate and land use changes and their impact on natural processes (e.g. hydrological cycle). This should be done through various case studies characterized by specific geographic contexts. Furthermore quantification of hydrological services needs to be improved and various operational indicators defined in order to better contribute to spatial planning and resource management.

The study aims to tackle these challenges through statistical analyses of the complex links between LC and hydrological response at the catchment scale in Wallonia (Belgium). Part of the originality of this

work lies in the fact that it is based on data which are monitored in the European context and quite easily available (discharge, LC, soil, rainfall data, etc.). This choice has been made to ensure the methods' replicability.

Data and / or method

The analysis is based on data describing the studied catchments and the drivers of the system: LC national data (including the distinction between broadleaved and needle leaved forests), soil national map, monthly rainfall data, daily discharge data, geological data through the main aquifers information layer.

The methodology uses uni- and multivariate statistical analyses in order to describe the links between ecosystems – and thus functions and processes – and services. Firstly, synthetic variables describing the hydrological response of the catchment are extracted from the 10 years discharge data series. These variables are extracted for different periods of time (i.e., annual, monthly, seasonal). The dataset is described (response and explanatory variables) through multivariate analysis (Principal Component Analysis (PCA) and Redundancy Analysis (RDA)). Then, multivariate analysis is used to measure annually the impact of LC on the response variables through RDA and variation partitioning. This is completed with univariate analysis (i.e. annual multiple regression analysis) to test selected dependent variables.

Main results

Results indicate that LC differently impacts ES (quantity and timing of water supply and flood mitigation) and that this impact is also driven by other variables (e.g. climatic data, physical characteristics of the land surface) making the research question complex to answer but also questioning the use of LC proxies to represent ES. Indicators of water related services are defined and discussed regarding their ability to address the assessment, mapping and monitoring of services.

Conclusion

One main objective of our methodological choices is to ensure the methods' replicability (see above). The same kind of analysis could be applied on temperate regions from countries which have a stream discharge monitoring (e.g France). Also this study brings information on indicators that can be used to quantify ES. The information brought up by this work is food for thought on the use of LC proxies to represent ES.

Acknowledgements

The authors acknowledge the Royal Meteorological Institute of Belgium (RMI) for sharing monthly rainfall data over 10 years on the territory.

PAYMENTS FOR WATERSHED SERVICES AND SOCIAL JUSTICE: BOLIVIAN HIGHLIGHTS

Bétrisey Florence,
University of Lausanne, Institute of Geography and Sustainability,

Florence.betrisey@unil.ch

Key words (5 at the most)

Payments for ecosystem/watershed services, market, reciprocity, social justice, environmental justice , Bolivia

(3.1;3.2;3.5)

Topic of this work

In 2003, the *Natura Bolivia* Foundation (a local NGO that receives funding from international donors) began to implement the principle of *Payment for Watershed Services* (PWS) in the province Florida

(eastern Bolivia) through a project called "*Reciprocal Water Agreements*" (RWA). This initiative aims to protect the forest covering the upstream watershed area as well as guarantee water resource quality and quantity (based on the supposed link and more or less modeled between forest conservation and quality regulation downstream flow). To do this, it connectsupstream and downstream actors of local watersheds through contractualized exchange relationships and the creation of a new institution named "local water fund". Downstream institutional actors (mainly water cooperative members and municipal authorities),framed as the water users or "beneficiaries of water services",financially contribute to thisnewly created "water fund".Once collected, the financial resourcesareused to compensatefarmers in upstream areas who agreed to put part of their land in conservation (waived their cultivation, restricted agricultural and livestock activities in a limited portion of their territory) and are thus regarded as "providers" of these "water services". Compensation is "in-kind" and consist of what *Natura Bolivia* calls "*productive alternative*" namely beehives, cocoa and other fruit tree plants or water tanks depending on farmers election.

According to *Natura Bolivia*, this initiativeaims at both improving sustainable watershed management but also the living condition of upstream farmer communities that experience a situation of poverty, exclusion and marginalization from infrastructures of the municipal territories to which they officially belong.

Research question (or operational application)

What are the socio-political outcomes and impacts of a *Payments for Watershed Services* initiative developed in rural Bolivia, in terms of socio-environmental justice?

Originality of this work

Payments for watershed services are deriving part of their legitimacy from their theoretical potential to reduce poverty. Indeed, there is a common belief that PES and poverty reduction come together in a "*win-win approach*" (Pokorny et al. 2012:388). However, previous investigations on PES and poverty reduction have focused primarily on the financial dimension of the redistribution of benefits and increased revenue(Petheram & Campbell, 2010). Here we want to go beyond these utilitarian visions and consider socio-political outcomes and impacts of PES in their potential to increase or reduce social justice among participants and non-participants.

According to Fraser (2004) we consider here social justice as a three-fold principle composed of the three irreducible conditions of redistribution, recognition and political participation.

Data and / or method

Following a qualitative approach, we conducted threephasesoffield research (2012, 2013 and 2014)in 14communities in whichwe conducted one hundred semi-structured interviews. We alsoconducted16interviews withrepresentatives ofdownstream actorsparticipating in thefund.Finally we conducted participative observation in communityand municipalmeetings.

Main results

We show that such initiative have potential to increase social justice for participants even if this potential is not systematically realized. By changing the scale of analysis, we also show that situations of injustice and exclusion can persist and even sometimes be strengthened by the new RWA institutions, especially between participants and non-participants.

Conclusion

Through our qualitative approach, we were able to go beyond theanalysis ofthe utilitariandimension ofPWS initiativeto reflect itshedonicvaluation; ietaking into accountthe symbolic but also political dimension of those initiative and their impacts on local societies.

References

Fraser, N. (2004). Justice sociale, redistribution et reconnaissance. *Revue du MAUSS, n^{o} 23*(1), 152-164. http://doi.org/10.3917/rdm.023.0152

Petheram, L., & Campbell, B. M. (2010). Listening to locals on payments for environmental services.

Journal of Environmental Management, *91*(5), 1139-1149. http://doi.org/10.1016/j.jenvman.2010.01.002

Pokorny, B., Johnson, J., Medina, G., & Hoch, L. (2012). Market-based conservation of the Amazonian forests: Revisiting win–win expectations. *Geoforum*, *43*(3), 387-401. http://doi.org/10.1016/j.geoforum.2010.08.

YOUTHS' PERSPECTIVES ON ECOSYSTEM SERVICES AT THE RIVER LANDSCAPE TRAISEN

Kerstin Böck, Michaela Poppe, Sigrid Scheikl, Andreas Loach, Susanne Muhar

Institute of Hydrobiology and Aquatic Ecosystem Management (IHG), University of Natural Resources and Life Science, Vienna, Austria

kerstin.boeck@boku.ac.at

Key words (5 at the most)

ecosystem services, perceptions, youths, river landscape Traisen

(sub topic 3.2)

Background and Objective

The Ecosystem Services (ES) concept has been increasingly used to address the multifunctionality of river landscapes. It addresses the interface between nature and human wellbeing and focuses on the multitude of services that river landscapes provide for humans (MA,2003).While there are several studies on the assessment of supporting (ecological services e.g. habitat function), provisioning (e.g. provision of water and food) and regulating (e.g. flood protection) services, cultural services (e.g. aesthetics, recreation) are given less consideration (Chan et al. 2012) and are inadequately integrated within assessment methods (Brancalion et al., 2014). Their assessment relies on people's perceptions who interact with the respective ecosystem (Brancalion et al., 2014).

As one of the largest user groups of cultural services children and youths can play an important role (Tapsell, 1997; Tunstall et al., 2004). Their views can contribute to improve the usability of river landscapes e.g. for recreational use (Tapsell et al., 2001).However, up to now there is only a limited number of studies dealing with the perception of children and youths in river landscapes.

In this study we address this knowledge gap and investigate how highschool students perceivecultural and ecological services that are provided by river landscapes.

Methods

Case study region

The investigations for this study were conducted in the catchment area of the river Traisenin Lower Austria. Despite manifold pressures, this river landscape provides many possibilities for recreation. Currently a LIFE+ project in the confluence area of the river Traisen into the Danube is conducted to improve the ecological functionality of the river landscape and ensure fish passability (Verbund, 2015).

Survey

During workshops and excursions highschool students were encouraged to foster their understanding for ecological processes in the river landscape Traisen. The ecosystem services concept was used as communication and education tool to address different perspectives towards river landscapes and make them more tangible. Semi-standardised questionnaires were applied to investigate youths' perceptions of ecological and cultural river landscape functions.

First results

The youths involved in this study associated cultural (e.g. "recreation", "swimming",…) and ecological river functions (e.g. "fish habitat", "diversity of plant species",…) particularly often with the river landscape. Figure 1 shows that from the group of cultural services "space for movement" and "restfulness" were described as the most important services. The ecological services "habitat" and "preservation of the state of the ecosystem" and the regulating services "flood protection" and "reduction of pollutants" were valued similarly high.

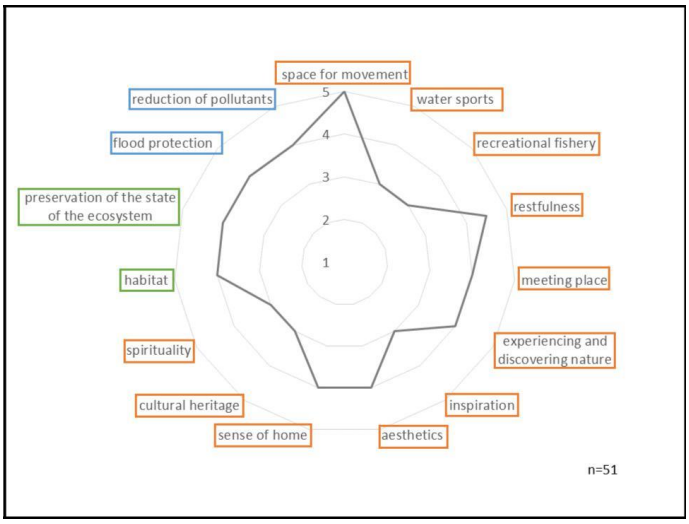


Figure 1: Youths' perceptions of the importance of cultural and ecological services at the river landscape Traisen. Orange : cultural services, green: supporting/ecological services, blue: regulating services

Discussion

The results reveal that the awareness regarding non monetarily usable ecosystem services is particularly high which corresponds well with earlier studies (Chiari, 2010; Böck et al., 2013). However, it is not consistent with the little consideration of these services in practice where provisioning services are prioritized-also due to the better quantification and measurability (Daniel et al. 2012; Schaich et al. 2010, Böck et al. 2013). This discrepancy stresses the need of attaching more importance to cultural and ecological services in future and give them more weight in future decision making processes.

Acknowledgements

This project is part of the research programme “Sparkling Science” that is funded by the Austrian Federal Ministry of Science, Research and Economy.

References

Böck, K., Muhar, A., Oberdiek, J., Muhar, S., 2013. Die Wahrnehmung von fließgewässerbezogenen „Ökosystemleistungen“ und Konfliktpotenzialenam Fallbeispiel „Flusslandschaft Enns“. Österreichische Wasser- und Abfallwirtschaft 11-12.

Brancalion, P. H. S., Cardozo, I. V., Camatta, A., Aronson, J., Rodrigues, R. R., 2014. Cultural ecosystem services and popular perceptions of the benefits of an ecological restoration project in the Brazilian Atlantic Forest.RestorationEcology 22(1), 65-71.

Chiari, S., 2010. Raumbedarf für multifunktionale Flusslandschaften-potentielle Synergien zwischen ökologischen Erfordernissen und den Bedürfnissen der Freizeit- und Erholungsnutzung. PhD thesis, University of Natural Resources and Life Sciences, Vienna.

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M. A., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P. H., Grêt-Regamey, A., Lave, R., Muhar, S., Penker, M., Ribe, R. G., Schauppenlehner, T., Sikor, T., Soloviy, I., Spierenburg, M., Taczanowska, K., Tam, J., von der Dunk, A., 2012. Contributions of cultural services to the ecosystem services agenda. Proceedings of the National Academy of Sciences.

MA (Millennium EcosystemAssessment), 2003. Ecosystems and human well-being: A framework for assessment. Island, Washington, D. C.

Plieninger, T., Bieling, C., Ohnesorge, B., Schaich, H., Schleyer, C., Wolff, F., 2013. Exploring Futures of Ecosystem Services in Cultural LandscapesthroughParticipatory Scenario Development in the SwabianAlb, Germany. Ecology and Society 18(3).

Poppe, M., Zitek, A., Scheikl, S., Preis, S., Mansberger, R., Grillmayer, R., Muhar, S., 2013. Erfassen von Ursache-Wirkungs-Beziehungen in Flusslandschaften: Vermittlung von Systemwissen in Schulen als Beitrag für ein nachhaltiges Flussgebietsmanagement. ÖsterreichischeWasser- undAbfallwirtschaft, 11-12, 429-438.

Schaich, H., Bieling, C., Plieninger,T., 2010. Linking Ecosystem Services with Cultural Landscape Research. GAIA 19(4), 269-277.

Tapsell, S., 1997. Rivers and River Restoration: a child’s-eye view. Landscape Research 22/1, 45-65.

Tapsell, S., Tunstall, S., House, M., Whomsley, J., Macnaghten, P., 2001. Growing up with rivers? Rivers in London children’s worlds. Area 33.2, 177-189.

Tunstall, S., Tapsell, S., House, M., 2004. Children’s Perceptions of River Landscapes and Play: What Children’s Photographs Reveal. Landscape Research 29/2, 181-204.

Verbund (2015, July 7). Life+ ProjektTraisen. Retrieved from http://www.life-traisen.at/de/projekt-life-traisen.

UNDERSTANDING THE EMERGENCE PATTERNS OF WICKED PROBLEMS IN ECOSYSTEM SERVICE AND WATER MANAGEMENT - THE PERSPECTIVE OF LONG-TERM ECOSYSTEM RESEARCH

Kinga Krauze, European Regional Centre for Ecohydrology PAS, Tylna 3, 90-364 Lodz, Poland, kingak@biol.uni.lodz.pl

Key words (5 at the most)

Wicked problems, socio-ecological systems, ecosystem services, networking, LTER

(1.3 Ecohydrology system solution and ecological engineering for the enhancement of water and ecosystem resilience and ecosystem services; 3.2 Stakeholder's perceptions of water related ecosystem services; 3.5 Water related ecosystem services – case studies in the urban and rural contexts)

Topic of this work

The "nexus" between water, food and energy, being also a competition for water and land, and between a limited set of ecosystem services, is one of the most fundamental relationships and challenges for society. The importance of this nexus was re-emphasised at the UN Conference on Sustainable Development (Rio+20) in June 2012. The source of the nexus – wicked problem - is often very local, and linked to demography, urbanization, raising footprint, and people's aspirations. It is however intensified and generalized by large scale processes like e.g. climate change and global market. Number of stakeholders involved, political complexity and different governance patterns led to the situation of unjust prioritization of some goods and services over the others, in management practices. That created a number of trade offs, where none of the solutions seems to be definitive, and none of stakeholders fully satisfied. Increasing awareness of human dependencies upon nature, which was introduced to the debate by approaches like ecohydrology, nature-based solutions, green-infrastructure, brought nature to the nexus, as another key stakeholder. If it is to be considered seriously also the need for spaces to secure delivery of ecosystem goods and services, maintaining ecohydrological regulatory patterns, and compensating the footprint, should be an important focus of management.

The questions of sustainability of ecosystem services delivery as well as wicked problems of management revealed a need for better understanding a co-evolution of humans and nature, dynamics of socio-ecological systems as a result of pressure – impact – response interactions, and changes in people's attitude towards both society and environment.

In its activities the International Long-Term Ecosystem Research Network, launched a set of cross-site studies based on in-situ data, to analyze delivery of ecosystem services as a function of management, the ability of people to assess the occurrence of ecosystem services, and changes in delivery rate, and the capacity of the network to define and address questions related to wicked problems in resource management

The capacity is understood as gathering and interoperability of properly set long data series, development of relevant research infrastructure and aggregating enough knowledge and expertise among scientists and practitioners.

Research question (or operational application)

There is a number of questions which have been posted by the society in general and LTER in particular, which we are trying to address as a network. Among them: What drives delivery of ecosystem services? How universal are the relationships between management regimes and ecosystem services sustainability? Which ecosystem services do we prioritize, which are unnoticed and what can

be the trade offs? Do we have any historical evidences? How the overview of people perceptions and demands can help in managing wicked problems? Do approaches like ecohydrology can contribute to this process?

Originality of this work

Due to its structure and functionalities, LTER is a unique network able to generate information on: 1) subtle, chronic changes in socio-ecological systems (e.g. triggered by climate change), 2) early warning signals based on the onset of acute changes, 3) rare, episodic, and/or complex events (involving socio-economic and socio-ecological drivers), when only long-term measurements help to isolate their dynamics and control processes, 4) vulnerabilities, resilience, recovery processes where socio-economic and ecological systems interact and adapt to each other, 5) specificity of cause-effect relationships resulting from socio-economic and environmental gradients, 6) indices, tools and methods enabling analysis of large data series, quantitative and qualitative information, trans- and interdisciplinary studies, and hard and soft syntheses.

The presentation shows the power of coordinated, networked and standardized analysis being only a part of ILTER research activities. The study looked at ecosystem service (ESS) delivery under different management scenarios with target to serve better definition of the management thresholds and trade offs, to understand the origin of wicked problems, and define the research capacities (data, sites, studies) needed to derive solutions.

Data and / or method

The data were obtained from questionnaires distributed during 3 subsequent studies: the first focused on evaluation of expert-based assessment of ESS occurrence and was conducted in 35 sites from 14 countries. The more detailed study analyzing changes in ESS delivery rate due to management shifts has been conducted in 19 sites of 17 countries. The analysis of ecological and social trade offs among ecosystem services, inherent in diverse management options, was conducted based on the data from 15 socio-ecological regions. The research covered environmental and economic gradients.

ILTER implements ISSE framework (Integrative Science for Society and Environment) and environmetrix for studying the ecological, social and economic factors and thresholds driving socio-ecological systems.

Exemplary results

1) In the LTSER platforms surveyors identified over 89 services. The regulating ecosystem services were found to be more difficult to assess, with the ecosystems' ability to remove metals or nutrients from the water and to reduce water born diseases and/or algal blooms, proving particularly difficult for site surveyors. The highest confidence was proven for cultural services.

2) Analysis of trends in ESS shows that a decrease is reported for 63%, 30% increase and stable are 7%. Sixty nine percent of all supporting services, 62 % of all provisioning services, and 79 % of all regulating services decrease. Among cultural services 48% decrease while 10% are stable and 42% decrease. The category cultural services has a 42% increase while regulating has only 16%.

3) Diversity of critical ESS is a function of societal use not necessarily ecosystem type.

4) There are clearly distinguishable ecosystem management approaches among LTER countries and sites from self-sustaining management to high reliability management. Trends and interactions between ESS are a function of management regimes, which are rooted in history, and societal and economic settings of sites.

5) As the wicked problems originate from the societal and management settings, LTSER and sister PECS approaches, incorporating socio-economic monitoring along ecological one, matching

administrative – environmental - research scales, and developing research around the core - multi-stakeholder platforms could be foreseen as nuclei of changes.

6) Ecohydrology, and other nature-based solutions require new type of management based on new types of leaderships. On contrary to past management strategies based on strong and dominating leaders, dealing with nexus requires communicativeness, big picture thinking, influencing skills, the ability to work cooperatively, to connect across the borders - the public, private and non-profit sectors, disciplines, and leverage created relationships to build networks of mutual benefit.

7) The 35 identified ILTER sites/platforms that participated in ESS studies represent no more than 2% of the current LTER members' sites/platforms (currently of more than 600) and demonstrated ability to contribute to broad scale research through the coordinated programmes. Incorporation of other sites, dedicated to more specific topic, and not belonging to the network, could become an asset in addressing more domain-linked questions.

8) There is an obvious need for more integrated data-bases and standardized approaches, to derive the information required to deal with challenges. The positive aspect revealed by cross-site studies is existence of that information and all required expertise, both from conceptual and analytical perspective. Also high importance of in-situ studies to understand large scale transformations has been demonstrated.

Aknowledgements

The study presents outcomes of collaborative work of ILTER Network members and sites coordinated by prof. Manuel Maas – the Chair of International Long-Term Ecological Research Network, the Institute for Ecosystem and Sustainability Research of the National Autonomous University of Mexico (UNAM)); dr Patrick Bourgeron – head of the ILTER Scientific Committee, University of Colorado Boulder, USA; dr Jan Dick - the lead of the task on ecosystem service identification , CEH, UK; All the colleagues from the LTER network.

MY RIVER IS NOT YOUR RIVER: RESIDENT AND EXPERT VALUES ASSOCIATED WITH AN URBAN RIVER IN A RESTORATION CONTEXT (YZERON RIVER, FRANCE)

Marylise Cottet, UMR 5600 EVS (CNRS), marylise.cottet@ens-lyon.fr

Marie Augendre, UMR 5600 EVS (CNRS)

Dad Roux-Michollet, GRAIE

Hervé Tronchère,UMR 5600 EVS (CNRS)

Key words: perception, value, restoration, river, landscape, mobile eye-tracking

(sub-topic 3)

Abstract

The management of urban rivers requires considering and reconciling multiple stakeholders that mostly have their own definition of river quality – which especially depends on the uses and values they associate with urban rivers. The consideration of these different views favours the identification and arbitration of all issues and the definition of more integrative projects. This challenge is especially strong when implementing a river restoration project: stakeholders must agree on the kind of river that should be restored.

To address this issue, and since environments are mainly experienced through the senses, we implemented a landscape assessment study. This paper presents the results of an eye-tracking experiment. It was carried out along the Yzeron River, a tributary of the Rhone River located in an urban area. The Yzeron River is being restored in several steps: a small section was restored in 2008, and a larger section is currently under restoration since 2014. Before this second stage, 27 residents and 20 experts were asked to walk along the waterway (in pre-restored and post-restored sections), wearing eye-tracking glasses. They had to assess, at predetermined stops, the quality of the scene, by answering a questionnaire.

The eye-tracking and the questionnaire data were qualitatively and quantitatively analyzed. The results underline that both experts and residents value "natural" rivers. But what they call natural is fundamentally different. Residents tend to value an arcadian nature where everything is under control and well maintained. Functional processes are only weakly considered when evaluating their environment, whereas experts refer above all to a functional nature for defining river quality. This difference of perception may partly relate to different points of views regarding the ecosystem services they link with an urban river.

'STREAM DAYLIGHTING' AS AN APPROACH FOR THE RENATURALIZATION OF RIVERINE SYSTEMS IN URBAN AREAS: ISTANBUL-AYAMAMA STREAM CASE[1]

Delibas Meltem[1, 2], Tezer Azime[2]

1-Turkish Water Institute, Libadiye Cd., No: 54, Kucukcamlica, Uskudar 34696, ISTANBUL/TURKEY and PhD Candidate, Istanbul Technical University, Faculty of Architecture, Urban and Regional Planning Department, Taskisla 34437 Taksim, ISTANBUL/TURKEY

2-Professor, Istanbul Technical University, Faculty of Architecture, Urban and Regional Planning Department, Taskisla 34437 Taksim, ISTANBUL/TURKEY

meltemdelibas@gmail.com, tezera@itu.edu.tr

Key words: Ecosystem services, ecohydrology, renaturalization,urban stream syndrome (USS), stream daylighting, Istanbul

(3.5 Water related ecosystem services – case studies in the urban and rural contexts)

Introduction

The world's population is concentrated in urban areas and urbanization became a dominant demographic trend as well as an important component of global land transformation (United Nations, 1993). According to Population Division Report of United Nations, Department of

Economic and Social Affairs (2001), the world‟s urban population reached 2.9 billion in 2000 and is expected to rise to 5 billion by 2030. On the other hand, in addition to its global reach, growing populations, changing consumption patterns, expansion of built-up areas and current low-qualified living of urban contexts are seen as unsustainable development patterns in the long term (Karr, 1999) with a number of documented effects on urban ecosystems. In particular, riverine systems as one of the most vulnerable components of urban ecology are exposed to the crisis of ecological deterioration. Due to increasing anthropogenic activities in urban areas, the functions of urban riverine systems have been gradually weakened, channels were polluted, buried and the riverine characteristics have been lost. All these negative effects on the urban riverine systems emerged the term of *'urban stream syndrome (USS)*' (Walsh et al., 2005) which is characterized by geomorphic and hydrologic alterations on riverine systems and described the consistently observed ecological degradation of waterways (creeks, streams, rivers) draining in urban areas. The conflict between riverine systems and human interfere with the growing pressure of urban development dynamics urges to investigate for a sustainable solution for a couple of reasons such as continuity of hydrological processes, access to fresh water,increased flood risk, climate adaptation, increased socio-cultural needs, biodiversity protection and so on. So far, mechanistic–hydrotechnical solutions have been developed for degraded riverine systems without considering social and ecological dimensions. Herein, the research focus on the integration of ecological and social systems while providing the mutual benefits for both nature and

mankind. Therefore,this research is based on a new paradigm called „ecohydrology‟ as an approach for renaturalization of degraded riverine systems in urban areas.

'Ecohydrology' is an interdisciplinary science harmonizing the use of specific tools of hydrology, engineering and ecology (Zalewski, 2002) for the benefit of human society and it can play an important role in sustainable water management (Jelev & Jelev, 2012). It provides engineering solutions with reduced environmental impact (Porporato, Rodrigez-Iturbe 2004) and bridges the fields of hydrology and ecology (Eagleson, 2002).

1 This paper is produced from MSc Thesis of the first author whichwas supported by The Scientific and Technological Research Council of Turkey (TUBITAK), Project No. 110K350.

On the other hand, as the urban stream syndrome illustrates, urban riverine systems are affected by multiple sources, resulting in multiple, co-occurring and interacting stressors. Especially in highly urbanized areas, channelization of urban streams reduces self-purification capacity and deteriorates water quality. Relatively, highly impermeable catchments reduce water retention and increase stormwater peak flows. At that point, Ecohydrology as anoverarching umbrella discipline, considers interrelations between catchment -as a template for water and nutrient dynamics- on one side, and habitat modification and biological processes-from ecological succession, biological productivity down to nutrients circulation by the microbial loop-on the other side (Zalewski, 2006).It also focus on the regulation of an entire range of ecological processes from the molecular to the landscape scale with a full understanding of water-biota interactions which is essential for improving a system having USS problems. Herein,the approach offers low-cost advanced technologies based on ecosystem processes for the problems of highly-complex and modified ecosystems (Zalewski, 2000). In the context of this research, the Ecohydrology approach is used as a framework in order to identify the interactionsamong ecological and hydrological components of the processes while providing possible solutions to achieve good ecological status (health) of the entire system.

The *'healthy rivers'* conceptrequires a river as an ecological system, not merely a channel that conveys water from one origin to downstream (Changming and Xiaoyan, 2008). The definition considers the system integrity and continuity especially for maintaining ecological processes of aquatic habitats and community of organisms. Asriverine systems are the major driving factor of fundamental ecological processes such ashydrological and nutrient (Carbon, Nitrogen, Phosphor) cycles (Zalewski, 2013), they are the main channelsofmass and energy exchange. They do not only provide important source and material transportation channels but also play an important ecological role as stream habitats (Lei and Guanghe, 2008) while providing various *ecosystem services*for the continuity of life on the Earth. These riparian areas are hotspots of interactions between plants, soil, water, microbes and human beings. They form unique ecosystems that act as „buffer zones‟ between up-streams and down-streams (Lowrance, 1998). Therefore, riparian zones are foci for human-nature interactions and can serve as catalysts for ecological and socioeconomic revitalization especially in urban contexts(Groffman et al., 2002).Although,urban riverine systems serve a variety of functions, ecological impacts of population growth and urbanization process on riverine systems are profound (Platt, 2006) and over the last couple of decades, river restoration has grown an important endeavor to overcome the long-term deleterious effects of human manipulation onrivers (CRSSR, 2012). Work to date, however, has focused solely on stream channel design and mechanics with focusing on a specific area with a narrow scope, while a holistic approach considering ecological processes and socio-economic systems withinthe integration of urban systems has been not widely used. Herein, the Ecohydrology approach provides a scientific background for enhancing water resources, maintaining and restoring biodiversity, providing ecosystem services for societies and building resilience to climate and anthropogenic

impacts (Zalewski, 2013). Most importantly, the approach is working for the expansion of nature-oriented thinking based on traditional methods to process-oriented thinking and offers a number of scientific applications and methodologies (Figure 1). „*Renaturalization'*as one of them, has a complementary role for a successful stream rehabilitation with focus on bringing a degraded riverine system to its original status in a naturalistic way. According to Ecohydrology approach, biota is the most dynamic and most vulnerable regulatory component of water cycle (Zalewski, 2000). Therefore, integrating water and biota at the catchmentscale through renaturalization is essential for biodiversity, water quality and quantity. In particular, the approach can be combined with „stream daylighting" techniques for degraded, buried or channelized riverine systems in urban areas. Stream daylighting describes the implementations that deliberately expose some or all of the flow of a previously covered river, creek, or storm water drainage system (Pinkham, 2000) mostly in highly urbanized areas.

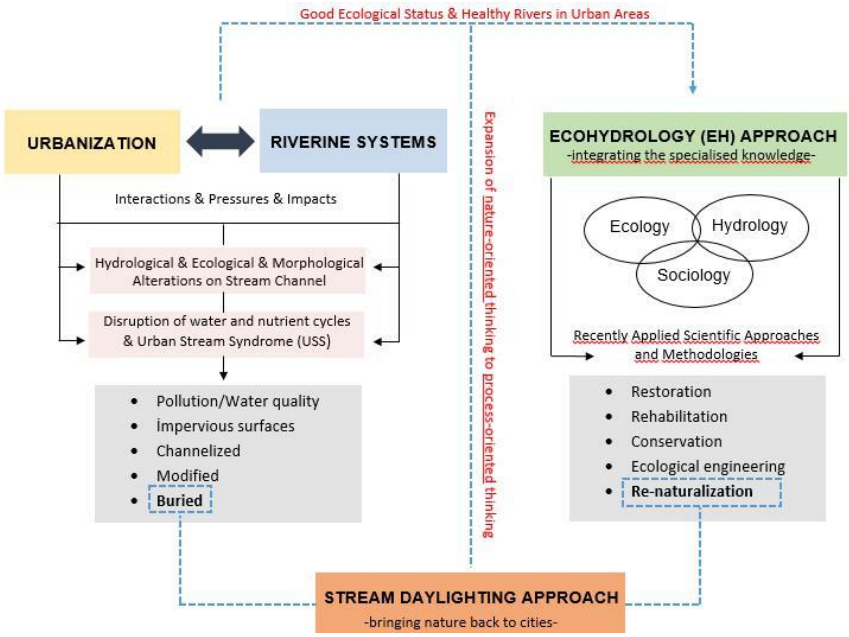


Figure 1: The concept scheme of the research.

As a conclusion, the efforts of renaturalization on daylighting help degraded riverine systems in urban areas to revert to their natural status and provide the opportunity of these systems tosupport mutual benefits toriverine systems and urban areas.Consequently, this paper focus on the interactions between riverine systems and urban areas including the role, importance and functions of riverine systems as well as the threats and problems they have been confronting from urban contexts in last decades. Since the „Ecohydrology" concept consists of diverse interventions such as restoration, rehabilitation, conservation and even re-naturalization of riverine streams where „Stream Daylighting" has its position as well,Therefore, the potential for 'Renaturalization' of buried riverine systems in urban areasis evaluated in this study through several case studies ofthe stream daylightingmethod implemented in different countries (USA, Canada, Korea, Switzerland). At the end, the achieved comparative results are used for developing a conceptual model and the model context is adopted to Ayamama Stream in Istanbul due to its problematic structure as a polluted and partly-buried stream channel in a denselyurbanized and over populated metropolitan urban context.

Material and methods

The methodology of the study consists of three main stages including conceptual literature reviews, conceptual model development and case study application.At the first stage, the research is based on descriptive analyses and conceptual reviewsdeveloped underseveral research questions. Secondly, 10 case studies (from 4 different countries) are selected from scientifically approved sources and analyzed in order to clarify the concept of daylighting from a broader perspective. The cases are assessed in terms of ongoing threats and challenges together withthe urbanization dynamics. According to the assessment results, a table is developed with the comparison of daylighting implementationsunder the economic, social, legal and technical aspects (Table 1). This comparison, provided a basis for comprehensive model development at the last stage. The produced model (Co-MISDAL) is preparedas a sample guideline for Ecohydrology based renaturalization efforts byusing stream daylighting methodfor buried riverine systems in urban areas. Also in the last stage, the conceptual model is adapted to Ayamama Stream case in Istanbul in order to definethe potentials and threats of the watershed area within Co-MISDAL framework.

PROJECT				TECHNICAL		ECONOMIC		SOCIAL	LEGAL & INSTITUTIONAL		RESULTS	
	Project Location	Year Completed	Primary Objective(s)	Length of Daylightened	Type of Imple-mentation	Total Cost	Funding	Land Characteristics	Legal Support	Stakeholders	Challenges	Benefits
1	**Napa Creek-San Francisco Bay, US**	1970's	Re-Explosion of a Hidden Stream (as a part of Urban Renewal Project)	Unavailable	Remove the concrete channel (only)	Un available	Un-available	Napa valley and settlement areas (densely populated area)	Unavailable	- Local Firms & Groups: - Urban Creeks Council - Wolfe Mason Associates	- Identifying the channel geometry, - Dealing with the problems of older urban infrastructure.	- Urban infrastructure benefits (expensiverepair costs). - Allows an increase in storm flow capacity.
2	**Strawberry Creek-Berkeley, California, US**	1984	Create a park and urban creek amenity by ecological restoration	200 feet + 4 acres for park area	Naturalization	$50 000 (US) + $580 000 park cost	City of Berkeley	Dense, mixed use area (near central business district) rail yard and university campus	Unavailable	-The city of Berkeley - Berkeley Youth Alternatives - University of California	Early model of a challenge that must be faced in nearly all daylighting projects: fear	- First example of daylighting, inspired many others - Shows the importance of public support - Property values increased
3	**Zurich, Switzerland**	Started in 1988	Seperating stream from sewage pipes	Over ten miles of project since 1988 to 2007	Naturalization	$5,000 (annual costs)	Zurich City Council	Densely populated urban areas	Swiss Water Protection Law and Citywide Policies	-Zurich City Council - The Stream Daylighting Group	- Citywide projects need different estimates for each implementation	- Significant reduction in loading to the combined sewer system - Flood mitigation

Table1: Assessment table of the implemented daylighting projects.

Theory/calculation

As a result of increasing degradation of riverine systems in urban areas and also weak interactions between urban ecological and social systems, the research aims to develop a conceptual model that can be used for the renaturalization of damaged/buried riverine systemsconsidering the holistic perspective of the ecological processes that can be studied by Ecohydrological methods. For his purpose, Co-MISDAL is developed as a final output of this research including the detailed analyses of case study assessments considering; primary goal/scope of the project, drivers for daylighting, feasibility assessment; challenges and limits, public reaction and participation, funding and stakeholders, legal background, positive impacts and lessons learned. The model tends to define the drivers in the background with possible stages, threats, opportunities, limits and challenges of daylighting implementations while guiding for future projects. At that point, the conceptual model is based on the Ecohydrology approach that considers creating a harmonious green, healthy and environmentally friendly, compact urban environments. Here, it is aimed with the model to provide a common platform for data and experience sharefor practitioners and decision makers.

Results

As a result of literature reviews, case study assessments and the detailed comparison of implemented daylighting projects, the „Conceptual Model of Integrated StreamDaylighting (Co- MISDAL)“ is developed for better understanding and integration of healthy riverine systems in urban areas (Figure 2).

The model has adopt a comprehensive framework considering the evolutionary relationshipbetween human & riverine systems to define the main drivers of the problem. Similarly, the plans and precautions developed by humankinds are evaluated as a response of societies for better interpretation of the process. Finally, the model defines the necessary tools for the most appropriate implementation of integrated steam daylighting based on the integration of ecological and social dynamics by using the synthesis of various daylighting implementations and ecohydrological indicators.In order to evaluate the efficiency of the model, the Ayamama Stream Corridor in Istanbul was chosen as a case study area due to its critical and problematic situation in a highly urbanized area (Figure 3).

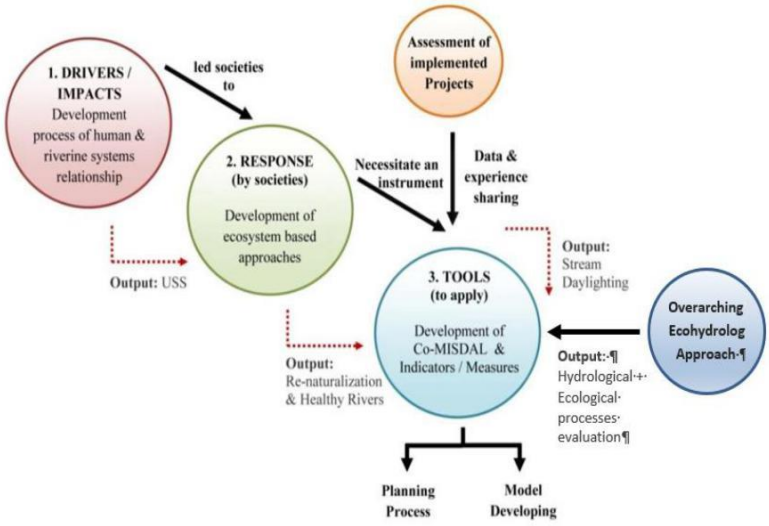


Figure 2: Development of the Co-MISDAL

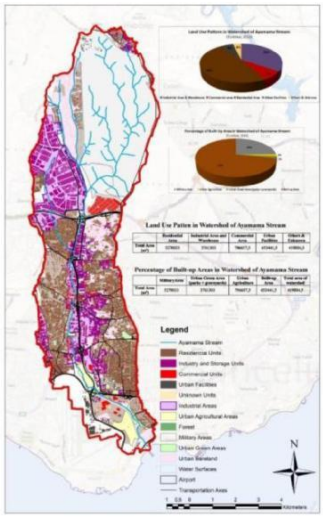


Figure 3: Current land use pattern of Ayamama Stream

The Watershed of Ayamama Stream stretches to21 kilometers (42 km with tributaries) length and consists of 6676 hectares with diverse land use patterns including industrial, commercial, military, agriculture and residential uses. Land use analysis of Ayamama Stream Watershed demonstrates that the majority (72%) of the watershed is built-up and mainly industrial and residential areas encompass the catchment area (Figure 3).On the other hand, significant floods have been experienced in Ayamama Stream between 1999 and 2009 with serious loses to people and properties. Also, industries and over population in the watershed area cause serious pollution problems effecting water quality and aquatic life negatively especially in the culverted, buried or channelized parts of the stream.

Discussion

The results of the research demonstrate that there is a sensitive balance between the functions of terrestrial (land) and aquatic ecosystems in nature. However, land use changes in urban environment have significantly been altering this balance, degrading the aquatic environment and resulting in causal

chain alterations on stream structure and functioning.In this framework, the watershed of Ayamama Stream, which includes six districts, constitutes a model for fragmented watershed system by both administrative units and land use patterns. The area is exposed to pressures of highly populated neighborhoods and dense agglomeration of industrial facilities on the stream banks. Urban facilities such as transportation networks, industrial and commercial activities and residential areas cover the majority of the land surface in the watershed area.Although, the highest pressure of human activities on streambed can be seen in the middle part of the watershed system, the 1/100000 scale Environmental Master Plan defined the area of Basin Express Road as a CBD (Central Business District) site.In order to clarify the contradiction between plans and projects developed for the Ayamama Stream, the Co-MISDAL offers to gather ecological, hydrological, physical, social, legislative and economic data while providing a comprehensive approach for the entire watershed area. The model divides assessment of the process in to four broad categories (environmental, socio-cultural, economic, technical) including the themes and sub-themes with defined numerical indicators (Figure 4). The indicators demonstrates the average/minimum/maximum values required for each theme for sustaining the mutual benefitsamong ecological and social factors. Ayamama Stream and its watershed isalso assessed under the key themes of the Co-MISDAL and the assessmentof Ayamama Stream case under Co-MISDAL framework is provided as a result of this research.

Conclusions

The ecohydrology concept is based on two assumptions. The first one is that water has been the major driver of biogeosphere evolution, as all ecological processes. The second assumption is on the basin scale, the hydrological cycle is a framework for quantification of hydrological and biological processes (Zalewski, 2013). From this point of view, restoration of ecological processes occurring within the hydrological cycle has a vital importance for each water resource facing with the problems such as urban riverine systems. Throughout the history, the expansion of anthropogenic activities led riverine systems to be polluted, culverted, buried or changed (hydro morphological structure).Therefore, in the context of this research, urban riverine systems are assessed in terms of their functions, problems and their interactions between socio-economic systems As a results of assessments a holistic approach considering physical, ecological, hydrological, and social properties of the system is developed to provide a database and a common platform for future daylighting projects. The model designed in the context of this, can be used as a basic tool and a guideline for understanding, planning and management of degraded riverine systems especially in highly urbanized areas.

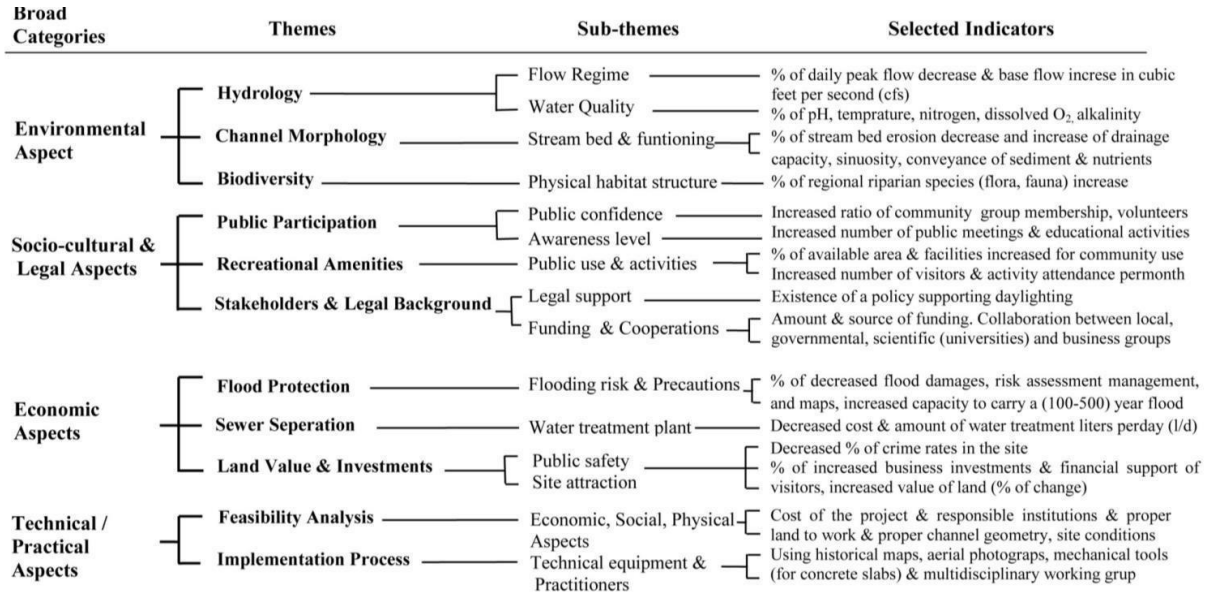


Figure 4: The general framework of Co-MISDAL

References

Changming, L., Xiaoyan, L., 2008. Healthy River: Essence and Indicators. Journal of Geographical Science,63(7) 683-692.

Center for Riverine Science and Stream Renaturalization (CRSSR), 2012.Availableat: http://www.umt.edu/rivercenter

Eagleson, P.S. 2002. Ecohydrology: Darwinian expression of vegetation form and function. Cambridge University Press.

Groffman, P. M., Boulware, N. J., Zipperer, W. C., 2002. Soil Nitrogen Cycle Processes in Urban Riparian Zones, Environ Sci. Tech., 36: 4547.

Jelev, I. and Jelev, V. 2012. An ecohydrology approach to the Danube River and the "enviroGRIDS" project, Ecohydrology and Hydrobiology, Vol. 12 (2), pp. 137-152.

Karr, J. R., 1999. Defining and Measuring River Health, Freshwater Biology,41,221-234, University of Washington, Seattle, USA.

Lei, Z., Guanghe, W., 2008. Urban River Plays Key Role in City LandscapePlanning Culture Legacy and Ecological Development, College of Urbanand Rural Construction, Hebei Agricultural University,Baoding, 071001,P.R.China.

Lowrance, R., 1998. Riparian forest ecosystems as filters for non-point-source pollution, In: Pace ML and Groffman P (Eds). Successes, Limitationsand Frontiers in Ecosystem Science. New York: Springer-Verla.

Pinkham, R., 2000. Daylighting: New Life for Buried Streams, Rocky Mountain Institute, Snowmass, Colorado, USA.

Platt, H., R., 2006. Urban Watershed Management: Sustainability, one Stream at a Time, Environment: Science and Policy for Sustainable Development, 48:4, 26-42.

Porporato, A., Rodrigez-Iturbe, I. 2004. Ecohydrology of water-controlled ecosystems: soil moisture and plant dynamics. Cambridge University Press, 450 pp.

United Nations, 2001. Population Division, Available at: http://www.un.org/esa/population/

United Nations, 1993. Human Development Report, Oxford University Press, Available at http://hdr.undp.org/en/media/hdr_1993_en_contents.pdf

Walsh, C. J., Roy A. H., Feminella, J. W., Cottingham, P. D., Groffman, P .M.,Morgan, R. P., 2005. The Urban Stream Syndrome: CurrentKnowledge and the Search for a Cure, Cooperative Research Centre forFreshwater Ecology, Water Studies Centre and School of Biological Sciences, Monash University, Victoria, Australia.

Zalewski, M., 2002. Ecohydrology-the use of ecological and hydrological processes for sustainable management of water resources. Hydro Sci. J, Vol. 47 (5), pp. 825-834.

Zalewski, M., 2006. Ecohydrology – an interdisciplinary tool for integrated protection and management of water bodies. Arch. Hydrobiol. (Suppl. 158/4): 613–22.

Zalewski, M., 2000. Ecohydrology-the scientific background to use ecosystem properties as management tools toward sustainability of water resources.Ecological Engineering, Vol. 16, (1-8).

Zalewski, M., 2010. Ecohydrology for compensation of Global Change. Brazilian Journal of Biology 70 (3) 689–695.

Zalewski, M., 2013. Ecohydrology: process-oriented thinking towards sustainable river basins. Ecohydrology & Hydrobiology, Vol.13, (97-103)

LE SYSTEME D'IRRIGATION TRADITIONNEL DANS L'OASIS DE BOUKAÏS (SUD OUEST, ALGERIE): REGLES DE PARTAGE, ORGANISATION SOCIALE ET PERENNITE

Ahmed Hamza Fellah, Abderrahmane Mekkaoui, Mohamed Madani

Les oasis sont des écosystèmes artificiels crées et maintenus par l'ingéniosité de l'homme Saharien au tour du facteur eau. Elles représentent un exemple d'adaptation aux conditions difficiles et un modèle de gestion intégrée des ressources naturelles dans les zones arides. Actuellement, un simple diagnostic de l'état de ces écosystèmes à travers le Sud algérien, montre que ces derniers sont dans un état très dégradé, du fait de la disparation du savoir-faire ancestral en matière de gestion d'eau d'irrigation. Cependant, quelques oasis comme celle de Boukaïs (Béchar, Sud-Ouest algérien) persistent depuis des siècles grâce au maintien de son système d'irrigation traditionnel ingénieux. Ce système est gravitaire basé sur l'eau jaillissante, connue localement « source de Boukaïs », fournissant un débit de 20l/s (Idrotecnico, 1976). Ces eaux sont acheminées vers les parcelles de la palmeraie à l'aide d'un réseau arborisant de canaux « Saguia ». La distribution de cette précieuse substance est gérée par des droits coutumiers et des règles conventionnelles de la communauté locale. La répartition de l'eau se fait selon deux modes, diurne et nocturne. Le jour, le temps est mesuré à l'aide d'une horloge solaire antique faisant de l'ombre d'homme et d'un mur une aiguille. Ce cadran découpe la journée en espace-temps irrégulier en fonction de la durée d'ensoleillement selon les saisons. Durant la nuit, le temps est mesuré à l'aide d'une jauge, qui correspond à un jalon gradué fixée sur le planché du bassin d'accumulation « Majen ». Ce dispositif permet la répartition de l'eau accumulée dans le « Majen » en volume régulier, dont l'unité de mesure de ce système est appelée « kharrouba » (FELLAH et al, 2014). Le partage de l'eau est fonction d'un calendrier d'irrigation de 21 jours. Chaque jour porte le nom d'un ayant droit d'origine, où la journée est repartie en 32 « Kharouba » qui correspond à 16 « Thman où 1/8 » (huit le jour et huit la nuit). Il assure le roulement, la rotation où cyclicité et l'équité. Au fil des années, les différentes transactions d'achat, vente, prêt et location ont modifié la propriété de l'eau, passant de la population d'origine vers d'autres nouveaux ayants droits qui sont actuellement au nombre de 60 ayants droits, tout en préservant l'ancien calendrier avec les journées des anciens ayants droits. Actuellement, l'eau d'une journée est exploitée par 4 à 8 irrigants. Le savoir faire et techniques sont transmis de génération à l'autres d'une manière orale et par apprentissage. Ce système de partage de l'eau reflète l'organisation sociale de la communauté locale et matérialise les logiques de fonctionnement complexe de la société oasienne. C'est un construit humain qui représente un témoin sur les rapports entre le groupes sociaux, il symbolise la culture d'adaptation, la maitrise de l'eau et le savoir vivre ensemble dans les zones arides. Il assure les objectifs de la gestion durable intégrée des ressources en eau. Ce système représente un témoignage sur le transfert et la transmission de savoirs faire et de techniques entre les deux rives de la méditerranée attesté par l'existence des systèmes analogues en Espagne (la Galice) et Portugal (Minho) (WATEAU 2005, 2006, 2007 et 2012). Le système d'irrigation traditionnel de Boukaïs est un patrimoine culturel et un caché identitaire. Il doit être préservé et valorisé. Il mérite d'être classé dans la liste des systèmes ingénieux de production agricole mondiale (SIPAM). Mots clés Oasis, écosystèmes, Irrigation, partage, gestion, intégrée, horloge, mesure.Indicate what are the domain and the problematic of your presentation.

THE VALUE OF URBAN FOREST IN THE RAINFALL-RUNOFF PROCESSES

E. González-Sosa,[a,b]. C. Véliz-Chávez[c], C. MastachiLoza[d] Becerril Pina[d] and N. Maricela

Ramos Salinas[b]

a) IRSTEA.Lyon, France. France.5 Rue de la Doua.enrique.gonzalez-sosa@irstea.fr

b) University Of Queretaro. Queretaro, Mexico.

c) University of Mexico valley. Queretaro, Mexico.

d) University of Mexico State. UAEMEX. CIRA.

Abstract

The urban forest functionality depends ofthe vegetation characteristics and behavior of precipitation. The urban vegetation regulates the runoff and drivesthe drainage systems and reduceswater pollution arising from wash load of streets and buildings, which has advantages ecohydrological. This present study about the rainfall interception was carried out and implemented in a deciduous *Ficusbenjamina (L.)* tree to evaluate the interception losses as well explore as the dynamics of interception regulate of runoff in urban zones. During of summer to autumn 2005, and spring to autumn, 2006 the rainfall was recorder. Measurements of gross precipitation (P_g), throughfall and meteorological data were recorded every 5 minutes.For the studied period, 151.59 mm of rainfall on 2005 and 203.35mm of rainfall occurred on 2006. Canopy interception was 59.46% and 70.98% of the gross rainfall (P_g) for the first and second year, respectively. Throughfall data recorded during 2005 was 38.14% (of P_g) and 27.21% (of P_g) during 2006(Table 1). The results of modeling indicated that urban forest adjusts the volume of runoff adjusted peak discharge and concentration time.Moreover was observed that these adjustments depend of architecture of trees and rainfall intensity (Fig.1).

Key words: Rainfall losses. Rainfall-Runoff in urban zone.Urban forest.Throughfall.Water pollution.[3].[3.5]

Table1. Resume of volume to each rainfall event and repartition of volume of troughfall and rainfall losses observed and modeling.

	Rainfall events		Throughfall		Volume				
Date	Pg	Intensity	Observed	Modeling	Pg	Th Observed	Th Modeling	EI observed	EI modelling
	(mm)	mm h^{-1}	(mm)	(mm)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)
07/20/2005	5,57	4,46	0,13	0,42	3,35	0,08	0,27	3,27	3,08
07/21/2005	1,52	6,08	0,25	0,02	0,65	0,16	0,02	0,49	0,64
08/09/2005	3,30	13,20	0,52	0,16	1,42	0,34	0,11	1,08	1,31
08/22/2005	2,79	16,74	0,41	0,12	0,90	0,26	0,08	0,64	0,82
08/25/2005	3,79	6,50	0,20	0,21	2,10	0,13	0,14	1,97	1,96
21/04/2006	2,41	3,62	0,23	0,08	1,55	0,15	0,05	1,41	1,50
27/04/2006	3,29	8,24	0,51	0,16	2,13	0,33	0,10	1,80	2,02
02/05/2006	3,10	1,03	0,31	0,14	1,33	0,20	0,09	1,14	1,24
30/05/06	2,20	2,93	0,17	0,07	1,26	0,11	0,04	1,15	1,22
02/08/2006	1,40	3,36	0,17	0,02	0,72	0,11	0,01	0,61	0,71
04/08/2006	15,90	4,34	2,41	2,15	10,02	1,56	1,38	8,47	8,64
05/08/2006	6,60	9,90	0,96	0,55	3,73	0,62	0,36	3,11	3,37
15/08/2006	12,30	11,35	0,92	1,47	7,32	0,59	0,95	6,73	6,38
18/08/2006	5,60	8,40	0,51	0,42	3,16	0,33	0,27	2,83	2,89
31/08/2006	12,00	4,36	1,84	1,41	7,51	1,19	0,91	6,32	6,59
14/09/2006	3,90	6,69	0,28	0,22	2,16	0,18	0,14	1,97	2,01
30/09/2006	41,60	9,24	5,89	8,36	26,34	3,80	5,39	22,54	20,94
14/10/2006	15,90	5,02	1,67	2,15	9,99	1,08	1,38	8,91	8,60
21/10/2006	35,80	9,99	4,41	6,80	22,55	2,84	4,39	19,71	18,17
02/07/2007	16,10	12,88	2,18	2,18	9,69	1,41	1,41	8,29	8,28
05/07/2007	2,60	3,47	0,10	0,10	1,49	0,06	0,06	1,43	1,43
06/07/2007	10,90	5,45	1,83	1,22	6,74	1,18	0,79	5,56	5,95
07/07/2007	9,10	4,04	1,20	0,92	5,65	0,78	0,60	4,88	5,06
02/09/2007	12,20	3,40	1,25	1,45	2,56	0,81	0,93	1,76	1,63
03/09/2007	7,20	7,85	0,48	0,64	4,22	0,31	0,41	3,91	3,81
TOTAL	**237,08**	**172,55**	**28,83**	**31,46**	**138,55**	**18,60**	**20,29**	**119,95**	**118,26**

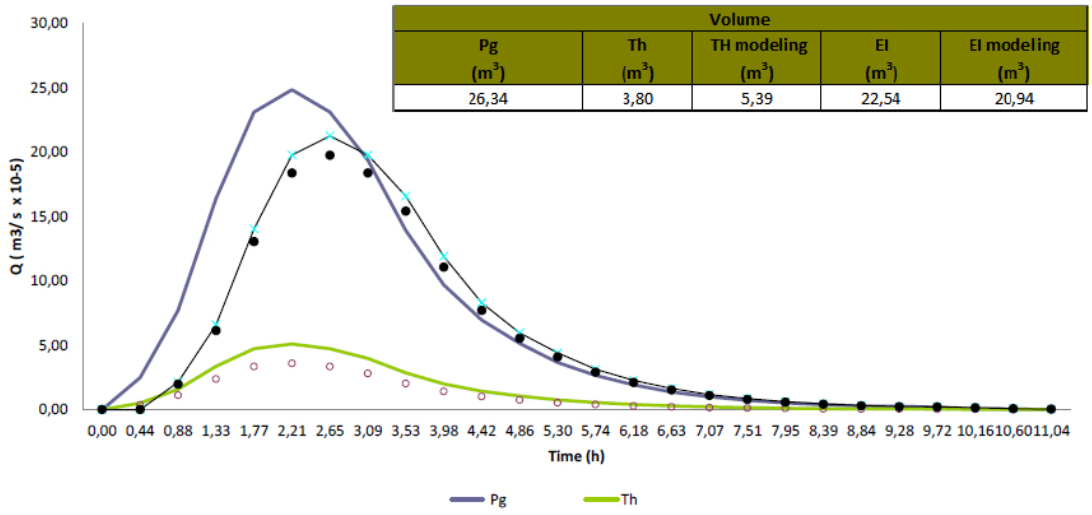


Figure1. Hydrogramcreated without rainfall losses (Pg, blue)and take accountthe rainfall losses(Pg-Th,), and throughfall (Th,yellow). The pointscorrespond at values observed.

UNESCO-IHP Program Ecohydrology 2015 Conference in Lyon France

The value of urban forest in the rainfall-runoff processes

E. González-Sosa,[a,b]. C. Véliz-Chávez[c], C. Mastachi Loza[d] Becerril Pina[d]. Isabelle Braud[a] and N. Maricela Ramos Salinas[b]

a) IRSTEA. Lyon, France. France.5 Rue de la Doua. enrique.gonzalez-sosa@irstea.fr. b) University Of Queretaro. Queretaro, Mexico. C) University of Mexico valley. Queretaro, Mexico. d) University of Mexico State. UAEMEX. CIRA.

The urban forest functionality depends of the vegetation characteristics and behavior of precipitation. The urban vegetation regulates the runoff and drives the drainage systems and reduces water pollution arising from wash load of streets and buildings, which has advantages ecohydrological. This present study about the rainfall interception was carried out and implemented in a deciduous *Ficus benjamina (L.)* tree to evaluate the interception losses as well explore as the dynamics of interception regulate of runoff in urban zones. During of summer to autumn 2005, and spring to autumn, 2006 the rainfall was recorder. Measurements of gross precipitation (P_g), throughfall and meteorological data were recorded every 5 minutes. For the studied period, 151.59 mm of rainfall on 2005 and 203.35 mm of rainfall occurred on 2006. Canopy interception was 59.46% and 70.98% of the gross rainfall (P_g) for the first and second year, respectively. Throughfall data recorded during 2005 was 38.14% (of P_g) and 27.21% (of P_g) during 2006 (Table 1). The results of modeling indicated that urban forest adjusts the volume of runoff adjusted peak discharge and concentration time. Moreover was observed that these adjustments depend of architecture of trees and rainfall intensity (Fig.1).

Key words: Runoff, Urban Forest, Rainfall interception

Introduction

Around the world floods are becoming more catastrophic, especially in urban zones where there are a high inter-annual variability of precipitation that affect of drainage systems. Studies on this kind of Ecohydrological environment would allow us understand the mechanisms that determine the rate precipitation-runoff processes.

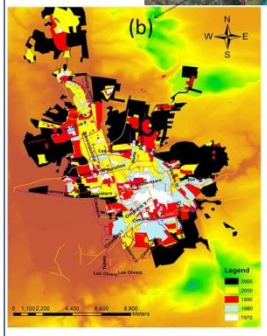
Objective

The work aim was to provide a better understanding of the value of urban forest in the rainfall-runoff processes, specifically through two objectives (1) to quantify and to model the rainfall interception process (E_i) employing an adequate sampling strategy and an evaluation of the models developed by Rutter *et al.* (1975) and Gash (1979) *in Ficus benjamina (L)*, and (2) to quantify runoff volume reduction by urban forest.

Methodology

The experimental study was carried out in a 15 year-old non-deciduous *Ficus benjamina L.* tree located in the main campus of the Universidad Autonoma de Queretaro. Rainfall data collected in the study site were made during the years 2005 and 2006. Furthermore, the application of the Rutter and Gash model with two years rainfall data. Hydrographs for individual trees of Avenue Belen trough rational method was elaborated, using of linear theory by integrate the runoff.

Fig.1 Location of Queretaro River Basin



a) The Queretaro city is located at northern of Mexico from central plateau. The city is situated under valley edge and, the altitude gradually lower to western direction 2700 to 1880 m. b) The growth of urban zone during 1995 to 1999.

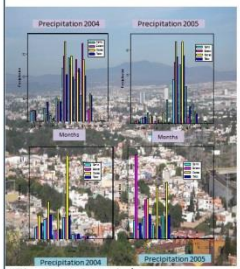


Fig.2. Spatial average of precipitation from 4 stations located in urban zone.

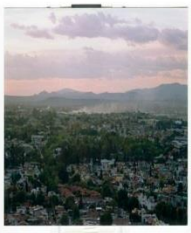


Fig. 3. View of Urban Vegetation.

Results

Fig 4. View of Belén avenue of Peñuelas catchment. N-W Queretaro City.

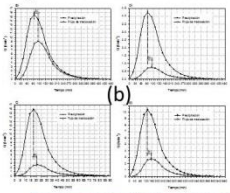


Fig. 5. (a) Precipitation accumulated and events (b) Hydrograph without and with *Ficus Benja. L*

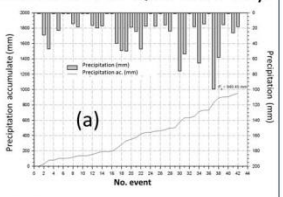


Fig.6. View of Belén avenue.
a) Current spot.
b) Hypothetical
c) Arrangement to increase of benefits by urban forest.

Conclusions: The interception losses by the *Ficus benjamina* delay the formation of surface runoff. Hydrogram for both individual trees and trees Belen Avenue, moreover the interception losses reduces the volume of runoff and time of concentration. The saving of costs of volume (7,53 m3) water pollution treatment is amount 1,97 dollar /m3.

Acknowledgements: This work was conducted with the support of: CONACYT (Fondos Sectoriales Semarnat-Conacyt and CONAGUA-CONACYT, 2010-2, NO 108173 and 148159). Also the student's participation is acknowledged. Also IRSTEA-HH Lyon.

Bibliography: Rutter, J. and Morton, A J., 1977. A predictive model of rainfall interception in forest. Sensitivity of the model to stand and parameters and meteorological variables. J. Appl. Ecol. 14, 567-588. Xiao, Q. and Mcpherson, E., 2003. Rainfall interception by Santa Monica's municipal urban forest. Urban Ecosystems. 6, 291-302. Zinke Paul J., 1967. The patterns of influence of individual forest tree on soil properties. Ecology. 43, 130-133

ASSESSING ECOSYSTEM SERVICES OF INSTREAM FLOWS: THE CASE OF THE TER RIVER

Dídac Jorda-Capdevila, Universitat Autònoma de Barcelona (UAB), dd.joca@gmail.com

Beatriz Rodríguez-Labajos, Universitat Autònoma de Barcelona (UAB), labajos_bea@yahoo.com

Key words

Ecosystem services, environmental flows, integrated valuation, participatory modelling, river restoration

Topic of this work

The preservation of instream flows entails multiple benefits, not only for the river ecosystems, but also for human well-being. Benefits of marketed goods and services provided by water withdrawals such as irrigation water supply and hydropower production are well studied. However, stemming from instream flows, others such as recreational, aesthetical, cultural and spiritual values of a well-preserved river are less known. Besides the increasing interest of policy makers to understand the benefits of costly river ecosystem-restoration measures, the poor assessment of them may turn into inter-stakeholder conflicts.

Research question (or operational application)

Motivated by the aforementioned, this paper: 1) reviews selected literature, which assess social and economic benefits of restoring/preserving environmental flows; 2) proposes a methodological framework for assessing the ecosystem services (ES) provided by river flows; and 3) illustrates this framework for the case of the Ter River (Catalonia, Spain).

Originality of this work

This work gives a broad overview of the value of restoring environmental flows and proposes an innovative methodology applied for the Ter River to illustrate social tensions among stakeholders.

Data and / or method

The review focuses on empirically-based analyses, offering the state-of-the-art concerning three aspects: 1) motivations behind the socioeconomic evaluation of instream flows (exploring policies and alternative instream flow regimes); 2) ES associated with instream flows (including the comprehensiveness of the analyses and stakeholders' engagement); and 3) methodologies employed to perform the assessments

(regarding scenario development, monetary and non-monetary valuations, etc.).

Building on this, we propose a methodological framework based on five steps of ES analysis:

- *Identification*: by asking in interviews how people benefit from river flows.
- *Characterisation*: by analysing the biophysical underpinning of ES provision.

- *Localisation*: by mapping ES provision in focus groups where different experts participate.
- *Quantification*: by modelling ES performance over time and space.
- *Valuation*: by running such modelling using different management scenarios regarding different views.

These steps are finally applied for the Ter River case, where excessive water extraction – e.g., for hydro-power, inter-basin water supply – alters the natural flow regime along the river. Traditionally, this situation has triggered local and regional disputes, becoming a main issue for water management

Main results

Our results show 28 ways of benefiting from the Ter River (Fig 1). The 15 ES closely related to river flows were selected and modelled in three different management scenarios: the business as usual (BAU), a future plan developed by the water administration (COM) and the management preferred by some environmental activists (ECO). Finally, a Service Provision Index (SPI) is calculated to show results over time and space, and to obtain tradeoffs and synergies among ES performances (Fig 2).

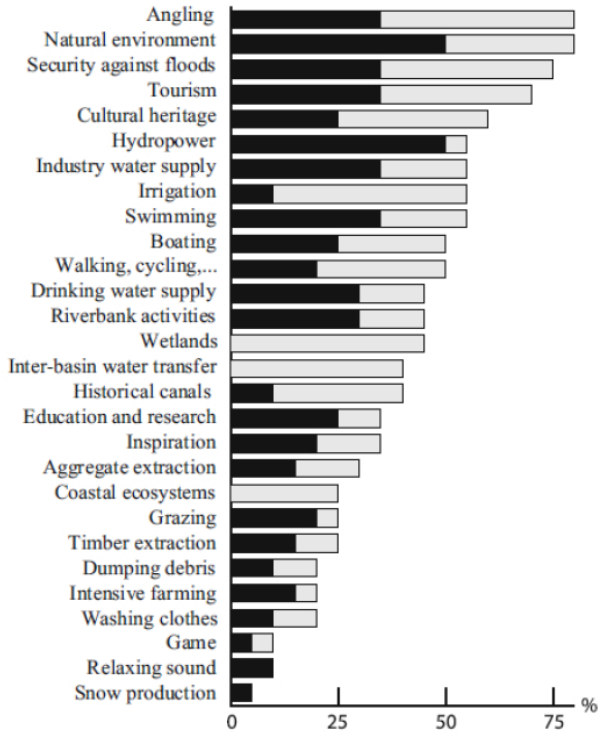


Fig 1. Identification of ES. In percentage, the amount of interviews where a specific ES appeared. In black, the Upper Ter; in light grey, the Lower Ter.

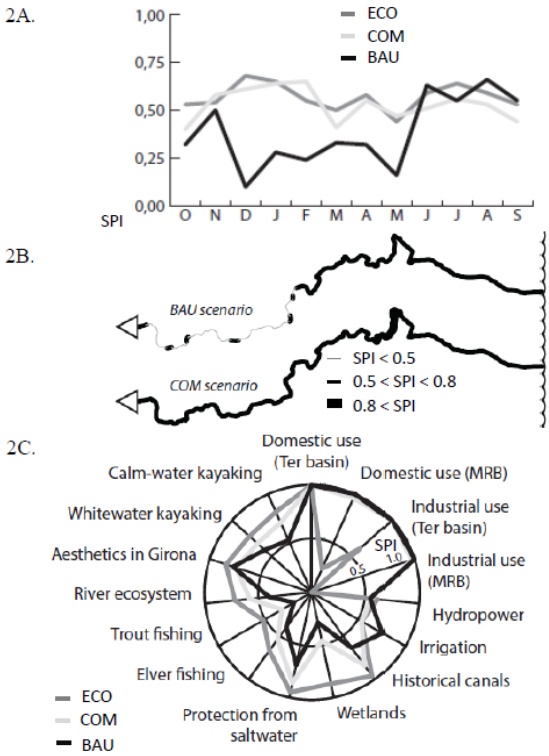


Fig 2. Examples of ES provision for different scenarios: 2A, calm-water kayaking over the year; 2B, ecosystem preservation along the river; and 2C, tradeoffs and synergies among ES

Discussion

An ecosystem services-based framework to assess environmental flows management is found to be useful to understand inter-stakeholder conflicts. 1) Stakeholders' engagement to identify and characterise ES helps to determine the socio-cultural factors behind conflicts that escalate when certain actors are ignored or marginalised. 2) Participatory modelling and mapping provides useful insights on spatial distribution, temporal distribution and tradeoffs/synergies of ES production. And 3) an

integrated valuation using the Service Provision Index enables a comprehensive assessment and puts all beneficiaries on the same level.

Acknowledgements

This work has been funded by the project CSO2010-21979 (Ministerio de Ciencia e Innovación) and it contributes to the BMBF funded project LEGATO and to EJOLT (FP7-SiS-2010-1). Our gratitude to J. Martin-Ortega (JHI) and K. Glenk (SRUC) for enabling a broad understanding of ecosystem services approaches; to M. Bardina and A. Manzano (ACA) for sharing all their knowledge related to water management in Catalonia, and M. Mulligan and A. van Soesbergen (KCL) for their help in the modelling process and the use of WEAP software. We also thank all stakeholders that participated in this work.

THE BEWATER PROJECT PROMOTES DIALOGUE BETWEEN THE SCIENCE AND SOCIETY ON THE FUTURE WATER MANAGEMENT IN FOUR MEDITTERRANEAN CASE STUDIES

Krivograd Klemenčič Aleksandra, Institute for Water of the Republic of Slovenia and Faculty of Civil and Geodetic Engineering University of Ljubljana, aleksandra.krivograd@izvrs.si
MagjarManca, Institute for Water of the Republic of Slovenia, manca.magjar@izvrs.si

SmolarŽvanutNataša, Institute for Water of the Republic of Slovenia, natasa.smolar@izvrs.si

Key words: Adaptation plan; Climate change; Mediterranean; Stakeholder participation; Water management

(3.2 Stakeholder's perceptions of water related ecosystem services)

Topic of this work

Stakeholder participation in water management.

Research question (or operational application)

The Mediterranean region is expected to become one of the most vulnerable areas in Europe and in the world regarding global change. Observational studies have already revealed a global trend toward warmer conditions and changes in seasonal rainfall patterns during recent decades.

The Vipava River Basin (RB) in Slovenia, LaTordera RB in Spain, Pedieos RB in Cyprus and RmelRB in Tunisia are four case studies selected in the BeWater project (7FP Science in Society) to making society an active participant in water management adaptation to global change. These four case studies are representatives of various Mediterranean conditions with regard to climate, topography, environment, socio-economic and political conditions, land use and water demands.

The overall aim of BeWater project is to promote an iterative dialogue and mutual learning collaboration processes between science and society to establish, using a multidisciplinary, bottom-up and participatory approach, plans for sustainable water management and global change adaptation in four Mediterranean River Basins (RBs). BeWater aims to (a) improve public awareness of the importance of sustainable water management, (b) develop innovative processes of mutual learning and (c) create more social responsibility in this area. These three factors are key to defining and implementing successful adaptation strategies and policies.

Originality of this work

BeWater aims to launch an innovative process of societal transition towards a more sustainable, resilient and adaptive river basin management. In the project context, transition means to foster mutual learning processes in order to change the way RBs are managed, focusing on Mediterranean region. Indeed, adapting to more adverse environmental conditions which may result from climate

change requires dynamic practices allowing citizens to actively play a role in the decision taking processes. This approach emphasizes the need to change with the environment and 'learning by doing'.

The selection of small RBs as case studies is essential for the BeWater approach. The choice of small areas provides a simplified complexity and facilitates understanding of the basic processes which underpin RB dynamics. Small areas, highly monitored and scientifically assessed, facilitate the identification, establishment and control of cause-and-effect relationships among processes involved, enabling the design of a methodology which can later be out-scaled and extrapolated to more complex systems. Additionally, essential links between society and territory are much stronger at this spatial scale.BeWater invites each case study RB to generate a specific adaptive management plan proposal and by sharing the experience, aims to pilot other RBs facing similar global change challenges.

Method

Within the BeWater project, two highly interactive stakeholder workshops (WS), additional interviews and individual or group sessions were carried out with the aim to identify, formulate and evaluatewater management options (WMOs) in each RB. In the first stakeholder WSround in 2014 and additional interviews,information on the current state and future expectations regarding water managementin each RB were identified. Afterwards, written and graphical narrative in the form of a Fuzzy Cognitive Map (FCM; a graphical representation of a system) of the RBs was developedwith active stakeholder participation based on main challenges identified. The development of the FCMswas done in parallel to the identification and formulation of WMOs to allow assessment of the impact of different WMOs by using the FCMs.The WMOs were characterized using a fixed set of descriptors. Withinthe second stakeholder WS round carried out in 2015, discussion and evaluation of WMOs with key stakeholders was performed. The evaluation of WMOs was carried out with the help of multicriteria analysis (MCA), wherefactors derived from the basin's FCM, and WMOs characterization criteria were used.In addition to a MCA, a simple cost-benefit analysis (CBA) will be performed for all WMOs, to help develop an adaptation management plan for the RBs.

Main results and discussion

The BeWater project is in progress and the following results are expected: Design realistic WMOs and an adaptation plan for each case study RBs; Foster environmental and societal resilience at river basin level through an integrated, stakeholder-driven water management planning;Enhance knowledge on water governance through collaboration between science and civil society; Strengthen public awareness on the urgency and relevance of tackling the effects of global change, as well as community empowerment towards adaptive water management;Share common challenges, lessons learned and best practices on adaptive water management planning in the Mediterranean and Transfer scientific results to policy options for response measures to face global change impacts.

Aknowledgements

This work was performed within the framework of theBeWater project,financed through 7th Framework Programme of the European Commission, under the Science in Society initiative, Grant agreement no: 612385.The authors are grateful for all the support.

WILLINGNESS TO PAY FOR WATERSHED CONSERVATION: ARE WE APPLYING THE CORRECT PARADIGM?

Makarius C.S. Lalika[ab1],Patrick Meire[a], Yonika M. Ngaga[c] and Goddy J. Sanga

[a]*Department of Biology, Ecosystem Management Research Group, University of Antwerp, Campus Drie Eiken,Universiteitsplein 1 BE-2610 Antwerp, Belgium.*

[b]*Department of Physical Sciences, Faculty of Science,Sokoine University of Agriculture, P.O.Box 3038 Chuo Kikuu, Morogoro,Tanzania.*

[c]*Department of Forest Economics, Faculty of Forestry and Nature Conservation, Sokoine University of Agriculture, P.O.Box 3011 Chuo Kikuu, Morogoro,Tanzania.*

[d]*Department of Agriculture Economics and Agribusiness, Faculty of Agriculture, Sokoine University of Agriculture, P.O.Box 3007KikuuMorogoro Tanzania.*

Key words: *Contingent valuation, Ecosystem services, Watershed ecosystem, Tanzania*

(**III-** The economic and social values of ecosystem services related to water)

Introduction

Background information

For decades watershed ecosystems have been taken for granted and the ecosystem services (ES) from therein have been regarded as free resources (Tietenberg, 2002) and sometimes considered as common (pool) property resources (Ostrom et al., 1993; Ostrom, 1990). Watershed ecosystems are potential for the provision of ES ranging from provisioning, regulating, supporting to cultural services (Costanza et al., 1997; De Groot et al., 2002; MEA, 2005). However, their socio-economic and ecological significance have subjected them to severe threats in such a way their potential to release watershed services has been dwindling (Liquete et al., 2011;Lalika et al., 2014). Analysis from the Millennium Ecosystem Assessment indicated that 60% of ES are under unsustainable use (MEA, 2005). Drivers for the degradation of watershed ecosystems include anthropogenic activities (such as unsustainable agriculture, excessive harvesting of forest products, mining activities, and overgrazing) and natural drivers such as climate change and variability(Lalika, 2015a; 2015b). This degradation has altered their long-term capacity to provide provisioning, regulating, supporting and cultural ecosystem services at levels that can sustain welfare of the current and future generations (Stanton et al., 2010).

The Pangani River Basin (PRB) presents a compelling case for analysis of the feasibility of payment for watershed services (Lalika et al., 2011; 2014). Kilimanjaro and Meru Mountains are regarded as the water towers because they are the catchment where Pangani River originates (IUCN and PBWO, 2008). The two catchments play an important role in providing fresh water to communities downstream. Their capacity to reduce run-off, percolate and slowly release water downstream has made the basin to become productive throughout the year. The watershed provide water for large and small scale irrigation, domestic and industrial use, hydropower production (at NyumbayaMungu

Dam); for ecological processes along Pangani River and for nutrient cycling at Kirua Swamp (Mwamila et al., 2008). Nevertheless, the increase of population along the PRB triggered the change of prior land uses to new ones in search for ES to support the growing population. Rampant population influx in PRB accelerated urbanization which called for more area for human settlement, agriculture and supply of water for the increased domestic and industrial uses. Consequently, the change of land use in search for watershed services has accelerated degradation of the watershed, hence reduction of water flow along the PRB(Lalika et al., 2015c).

To reverse the harm done on the watershed an integrated conservation approach which brings together upstream communities and downstream water users is deemed important to complement the traditional command and control policy instruments (Pagiola, 2008; Porras et al., 2008). Marked-based approaches for conservation have been tipped as ideal policy tools for watershed conservation (Locatelli and Vignola, 2009; Khanal and Paudel, 2012). The economic logic behind this argument is that the later instruments acting on their own have not been sufficient to address the problems facing the management of watersheds. In particular, command and control instruments have not exploited the potential of upstream land holders and downstream ecosystem services beneficiaries in achieving conservation goals. Market based instruments provide incentives to upstream land holders to manage the catchment in manner that ensure continued supply services to downstream users (Turpie et al., 2008). Equally important, marked based instruments are considered important as they will motivate upstream land holders to take into account the effects of their actions when making decisions about their own land use.

However, some key empirical analysis of downstream users who are willingness to pay for the services provided to upstream land holders is crucial before establishing the downstream-upstream market link (Whittington, 2002;Mohamed et al., 2012; Calderon et al., 2013). Therefore, this study based on the contingent valuation method (CVM) was carried out to elicit people‟s willingness to pay

(WTP) in order to gather information for designing and establishing PWS scheme. Specifically the study (i) Identified respondent‟s perceptions on WTP for watershed conservation (ii) Examined socio-economic drivers and marginal effects for WTP for watershed conservation; (iii) Determined the factors influencing the maximum amount for WTP for conservation.

[1] Corresponding author:
Sokoine University of Agriculture, Faculty of Science, Department of Physical Sciences, P.o.Box 3038 Morogoro Tanzania. Cell phone: +255 754 201306; Fax: +255 23 2604648; 255 23 2603404; E-mail address : makarius.lalika@yahoo.com;lalika_2mc@suanet.ac.tz

Material and methods

Location

This study was conducted in eight villages; four (Kaloleni, Chekereni, Rau River and Mabogini) in Kilimanjaro Region and the other four (Lekitatu, Karangai, Msitu wa Mbogo and Kikuletwa) in Arusha Regionthe Pangani River Basin **(Figure 1-Appendix I).**

Figure 1: Location of the study area along Pangani River Basin, Tanzania

The PRB is located at latitude 03º 05' 00" and 06º 06' 00" South and longitude 36º 45' 36" and 39º 36' 00" East. It drains a large catchment in the northeastern part of the country along the border with

Kenya, extending from Mount Meru and Kilimanjaro down through the Pare and Usambara Mountain ranges (IUCN and PBWO, 2008).

Hydrology and drainage pattern

The hydrology and drainage pattern in the PRB catchment varies considerably. The PRB comprises of several sub-catchments of widely different characteristics. The Pangani River (PR), which is also referred as the Pangani Mainstream, rises as a series of several small streams and springs on the southern sides of the Africa‟s highest peak Mt. Kilimanjaro, and on Mt. Meru. These streams

(Nduruma, Tengeru, Sanya, Malala, etc.) create the Kikuletwa and Ruvu Rivers (Himo, Muraini, etc.) which drain further downstream into the NyumbayaMungu (NyM) dam (IUCN and PBWO, 2011). The NyumbayaMungu dam has created a man-made water reservoir of ecological and economic importance along PRB. The overflow of the dam (outlet) is known as the Pangani River Mainstream and flows for 432 km before emptying into the Indian Ocean at the Pangani estuary.

Sampling procedure

Field visits were first carried out along the PRB for village identification and sampling purposes. A simple random sampling technique was used to select the sampling units in order to avoid bias. We used this sampling technique in order to give every member of the population an equal chance of being selected. The sampling frames for this study were the village registers containing the list of all household in the respective villages. We sampled 8 villages, 4 in Arusha Region and 4 in Kilimanjaro Region and in each village we sampled 10% of the total households. In each village, we randomly selected respondents using a table of random numbers. The respondents were selected by matching their numbers in the register. We used both quantitative and qualitative methods in data collection.

Questionnaire design and bid amounts

The questionnaire had the following sections: i) The valuation scenario (i.e. where we introduced the respondents the mission of our survey, types ES delivered by watersheds, why they should be conserved and paid for, etc.); ii) The status of watersheds (i.e. they are degrading and that continued degradation will result in significant reduction of ES and if they think conservation would restore the situation); iii) Initiatives set by the government and donor agencies on watershed conservation (i.e. if they are willing to contribute for increased unit of water flow; bids and payment methods); iv) If they are willing or unwilling to pay and why?; v) Certainty of their willingness and unwillingness to pay; vi) Their willingness to wait for longer periods in order ES to flow as a result of their payments and their opinions if they think PWS would enhance watershed conservation).We set questions in the form of binary/dichotomous, i.e. respondents had two options (1= yes and 0 =No). We designed bids amount in a form of payment cards assigned values (ranging from Tanzanian shillings 0 – 75,000 where respondents were required to mention or circle the amount they were willing to pay per year?. These bids were finally set after pre-testing.

Data analysis

We coded and cleaned the 360 questionnaires for final analysis. Thereafter, we used Statistical Package for Social Sciences (SPSS) version 20.0 to analyze data. There after we carried out analysis to obtain frequency and percentages of responses from smallholder farmers who were willing or not

willing to pay for watershed services. On the other hand, we analyzed qualitative data with the help of participants during group focus discussions through dialogue and intensive debates.

The empirical model

The study employed the Contingent Valuation Method (CVM) which is a hypothetical value based method used to estimate smallholder farmers‟ Willingness to Pay (WTP) for ecosystem services obtained from a watershed for sustainable management of the ecosystem. The approach was selected for this study because of its ability to assign a market value to ecosystem services which have no market values or cannot be assessed by market mechanisms (Bateman et al., 2002; Amponin et al., 2007).To achieve the objective of the study, we therefore, employed un-observed latent variable as an underlying propensity to WTP. To get consistent results, the survey data were analyzed using probit model as suggested by Green et al. (1995) to examine more rigorously whether or not small holder farmers in Pangani Basin are different between the two lines of choices.

The model used takes the following form:

$$y_i = \begin{cases} 1 \text{ if } y_i^* > \tau \\ 0 \text{ if } y_i^* \leq \tau \end{cases} \quad \ldots\ldots (1)$$

Where: τ is the threshold of being different between the two lines of choices, and y^* is the latent variable.As revived by Green (2003) the latent variable (y_i^*) is assumed to be linearly related with observed variables $(x's)$ in the structural model and is presented as:

$$y_i^* = x_i\beta + \varepsilon_i \quad \text{..... (2)}$$

Where; x is a vector of variables is hypothesized to influence WTP; β is a vector of parameters estimated; and ε_i is the random error assumed to be normally distributed with zero mean and unit variance (i.e. $\varepsilon \cong N(0, \sigma = 1)$.

The probability of observing a small holder farmers saying 'YES' (i.e. $y = 1$) is expressed as suggested by Long (1997)

$$\Pr(y_i = 1|x_i) = \Pr(y_i^* > 0|x_i) \Rightarrow \Pr(y_i = 1|x_i) = \Pr(x_i\beta + \varepsilon_i > 0|x_i) \text{..... (3)}$$

As mentioned in above, the probability of an individual to be willing to pay for watershed services was estimated by using logit model such that;

$$\Pr(y = 1) = \frac{\exp(x_i\beta)}{1 + \exp(x_i\beta)} = \frac{1}{1 + \exp(x_i\beta)} \text{..... (4)}$$

The parameter estimated were interpreted as marginal effects, which indicates the effects of a marginal change of the variables conditioning willingness to pay for watershed services on the probability of saying 'yes'. Therefore, the marginal effects were estimated as follows;

$$\frac{\partial \Pr(y = 1|X)}{\partial X_i} = \phi(x_i\beta)\beta_i \text{..... (5)}$$

Where: Y= is WTP taking values 0 and 1, X= is a vector of factors that condition individual WTP, and β= is a vector of variables estimated (Griffiths et al., 1993; Sanga et al., 2013).

Note: that Y is censored at zero for the sub-sample of smallholder farmers that gave valid responses. Thus, to get consistent and robust results, the two-limit probit model as suggested by Rosett and Nelson (1975) was used to allow both upper and lower censoring to be captured in estimating the likelihood function for the model (see eqs. 6 and 7 respectively).

$$y = \begin{cases} \tau_L & \text{if } y^* \le \tau_L \\ y^* = x\beta + \varepsilon_i & \text{if } \tau_L < y^* < \tau_U \\ \tau_U & \text{if } y^* \ge \tau_U \end{cases} \text{..... (6)}$$

The likelihood function was estimated as follows:

$$\ln L = \sum_{\text{Lower}} \ln\Phi\left(\frac{\tau_L - x\beta}{\sigma}\right) + \sum_{\text{Uncensored}} \ln\frac{1}{\sigma}\phi\left(\frac{y - x\beta}{\sigma}\right) + \sum_{\text{Upper}} \ln\Phi\left(\frac{x\beta - \tau_U}{\sigma}\right) \text{..... (7)}$$

Description of variable and model specification

Responses on WTP were denoted by binary answers (dummy variables) where the response of respondents was "yes" denoted by the 0 value and "no" for 1. Respondent's WTP for watershed conservation were hypothesized to be conditioned by a number of socio-economic drivers. It was hypothesized that variables denoted by positive (+) and negative signs (-)could influence positively and negatively people's WTP respectively. Thefull empirical model was specified as:

$$WTP = \beta_1(H2OUSEFE) + \beta_2(GENDER) + \beta_3(MARITALS) + \beta_4(EDUCAT) + \beta_5(OCCUPAT) + \beta_6(HHSIZE) + \beta_7(PROPTHHE) + \beta_8(TOTANNU + \beta_9(IRRIINCO) + \beta_{10}(NNHSOUC) + \beta_{11}(DISTASOU) + \beta_{12}(AMOH2OSO) + \beta_{13}(AMOH2OCO) + \beta_{14}(AMOH2ODR) + \beta_{15}(H2OUSWAS + \beta_{16}(H2OUSEDW) + \beta_{17}(H2OUSEDT) + \beta_{18}(PRICEH2O) + \beta_{19}(SIZELAND) + \beta_{20}(AMOPAIDI) + \beta_{21}(YIELDIPP) + \beta_{22}(YIELDNON) + \beta_{23}(H2OUSERI) + \varepsilon \text{.....(6)}$$

Where:

WTP = Willingness to pay for watershed conservation;

H2OUSEFE = Water use fee; GENDER = Gender; MARITALS = Marital status; EDUCAT = Education level; OCCUPAT = Occupation; = HHSIZE = Household size; PROPTHHE = Number household members engaged in income generating activities;

TOTANNUA = Total annual income; IRRIINCO = Irrigation income; NHHSOURC = Household water sources = DISTASOU = Distance from the water sources; AMOH2OSO = Amount of water from other sources; AMOH2OCO = Water used for cooking; AMOH2ODR = Water used for drinking; H2OUSWAS = Water used for washing clothes; H2OUSEDW = Water used for washing dishes; H2OUSEDT = Water used for toilets; PRICEH2O = Price for water = SIZELAND = Total land size; AMOPAIDI = Amount paid for irrigation;YIELDIRR = Yield with irrigation; YIELDNON = Yield without irrigation = and H2OUSERI = Water use for irrigation.

Results

Responses on respondent's WTPfor watershed conservation

As expected prior to this study, we found that majority of the respondents (79%) were willing to contribute for watershed conservation (Table 1-Appendix II). As indicated in the table below, majority of respondents preferred to pay between 6 (33.6%) and 12 (37.8%) months. These preferred time scale for payment links well with harvesting seasons where smallholder farmers in PRB have two farming and harvesting seasons.

Table 1: Responses on perceptions on WTP for watershed conservation

Furthermore, we found that majority of smallholder farmers (90.5%) were confident of their decision and ability to pay WTP. Reasons for their certainty for WTP include: their dependency on water for household and irrigation uses; sustainable water flow for future generations; watershed conservation for flow of ES; and watershed conservation to enhance ecological integrity. With regards to the marginal effects of conservation programmes, majority of respondents (78%) were willing wait for a unit increase water flow as an output of their payment for watershed conservation (Table 1-Appendix II).

Socio-economic drivers and marginal effects on water users' WTP

Table 2 (Appendix III)reveals drivers and their corresponding marginal probabilities for farmer‟s WTP where six variables indicated statistical significance on WTP at 1% ($p < 0.001$) probability level. They includes: marital status (MARITALS), education level (EDUCAT), household size (HHSIZE), total annual income (TOTANNUA), distance from the water sources (DISTASOU) and total land size (SIZELAND).

Table 2: Marginal probabilities for small holder farmer‟s willingness to pay for watershed services

Notes: ***, **, * indicates significance at 1%, 5%, and 10% levels of significance respectively

As expected in the hypothetical direction of the respondent‟s opinion (Table 2), marital status

(MARITALS), household size (HHSIZE), and distance from the water sources (DISTASOU) influenced positively respondent‟s WTP for watershed conservation. The positive sign for marital status (MARITALS) implies that the probability of married couples to WTP for watershed

conservation was higher than singles. Similarly, the positive sign for household size (HHSIZE) means that as the number of household members increases, the probability of WTP for that household increases as well. Moreover, the positive sign for the distance from the water sources (DISTASOU) implies that, as the distance from the water sources increase, it increases the probability of people‟s WTP for the construction of nearby water sources.

On the other hand, the education level (EDUCAT) and total annual income (TOTANNUA) had negative signs thereby reducing respondent‟s probability WTP for watershed conservation. The negative sign of the education level (EDUCAT) is implies that education level reduces respondent‟s probability for WTP for watershed conservation. Also the negative sign of the total annual income (TOTANNUA) implies that total annual income (TOTANNUA) reduces respondent‟s probability for

WTP for watershed conservation. These findings are contrary to the findings by Amponin et al. (2007) and Ferolfi et al. (2007) who revealed that income increase influenced people‟s WTP for watershed protection for domestic water supply in (Tuguegarao City) Philippines and Swaziland respectively.

Determinants of the amount for WTP for the watershed conservation.

Table 3 (Appendix IV)reveals factors that determine the amount that smallholder farmers are WTP. Factors that determined significantly this amount includes: education level, occupation, household size, irrigation income, water used for washing dishes, total land size (ha), amount paid for irrigation, and crop yield with irrigation.

Table 3: Maximum amount small holder farmer‟s WTP

Note: ***, **, * indicates significance at 1%, 5%, and 10% levels of significance respectively

The positive sign for education level, water used for washing dishes, total land size and crop yield with irrigation implies that these factors influenced positively on the probability of the amounts that respondents are WTP for watershed conservation. On the other hand negative sign for occupation, household size, irrigation income and amount paid for irrigation implies that influence negatively on the probability of the maximum amount that respondents are WTP for watershed conservation.

However, overall Table 3the WTP had positive influence on WTP and statistically in indicated a significant influence at 1% ($p< 0.000$) probability level. In addition, the goodness fit of the linear model explained 0.62 (i.e. 62%) variation of the variables used in the computation. The rest, i.e. 38% may have been affected by external factors including data acquisition, handling, processing and analysis.

Discussions

Overall, smallholder farmers have high level awareness on watershed conservation along PRB. This has been testified by their willingness to contribute (76%) for watershed conservation (Table 1).

Respondent‟s willingness to contribute for watershed conservation could be due to the high demand of watershed services (water) they need from therein. Due to climate change and climate variation(Lalika et al., 2015a), smallholder farmers depend much on irrigated agriculture, and this justifies their awareness and willingness to contribute for watershed.

The level and spirit of respondents to be WTP for watershed conservation (Table 1 and 3) is an encouraging indicator for the sustainability of watershed ecosystem. Majority of smallholder farmers in the PRB are willing to contribute for financing watershed conservation in order to ensure the sustainability of water flow.

Normally, education determines the level of awareness and willingness to participate and contribute for conservation initiatives. It is perceived that an educated person is civilized and can make wise decisions driven by accumulated knowledge through education (Mohamed et al., 2012). On the contrary, findings of this study indicated that education had negative influence on respondent‟sfor WTP. This observation differs completely with the theoretical assumption on education and the observation by Samdin et al. (2010) who asserted that *"in normality, decision making made by educated communities are more fundamental due to knowledge advantages they owned. Therefore, their decisions towards WTP are influenced by their developed knowledge rather than emotion driven decisions*".

Conclusions

The study has revealed that local communities are awareandare enthusiastic to contribute for financing watershed conservation for sustainable water flow. Furthermore, the study has indicated that CVM is a good policy tool for soliciting conservation funds from the users of watershed services. Also the study has testified that water use fees could be a potential and reliable revenue source for financing nature conservation programmes instead of relying on donor funding. Furthermore this study has revealed that there is a potential for generating funds from downstream water users to support upstream communities who would be willing to implement watershed conservation practices.Although CVM studies are normally hypothetical in nature (i.e. they depend on people‟s opinions) they are quite useful and have been extensively used in different parts of the world. Results from this study would be a basis for resource valuation in other areas in Tanzania facing similar problems like in the PRB.

Acknowledgements

The financial support for this work came from the government of Belgium (scholarship grant number 09TAN/5917) through the Belgium Technical Cooperation (BTC). Authors are grateful to research assistants MS. Mariam Ramadhani and Ms. Mariam Muya, for their tireless efforts during socio-economic surveys in the study villages.

References

Amponin, J. A., Bennagen, E., Hess, S., and Cruz, D.J., 2007. Willingness to pay for watershed protection by domestic water users in Tuguegarao City, Philippines. *Poverty Reduction and Environmental Management (PREM) Working Paper 07/06 ASEAN Center for Biodiversity*.[http://www.prem-online.org/archive/5/doc/PREM%20WP%2007-06] Visited 28March 2013.

Bateman, I.J., Carson, R.T., Day B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemigorlu, E., Pearce, D.W., Sugden, R. & Swanson, J., 2002.*Economic Valuationwith Stated Preference Techniques: A Manual.* Edward Elgar Publishing, Inc. USA.

Calderon, M. C., Camacho, L., Carandang, M., Dizon, J., Rebugio, L., and Tolentino, N., 2005.A water user fee for households in Metro Manila, Philippines.*Research Report for the Economy and Environment Program.*http://web.idrc.ca/uploads/user-S/11201068811MargeRR2[visited 19 February, 2015]

Costanza, R., d‟Arge, R., de Groot, R.S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O‟Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world‟s ecosystem services and natural capital.*Nature*387, 253–260.

De Groot, R.S., Wilson M.A. and Boumans, R.M.J., 2002. The dynamics and value of ecosystem services: Integrating economic and ecological perspectives. A typology for the classification, description and valuation of ecosystem functions, goods and services.*Ecological Economics* 41, 393 – 40827.

Farolfi, S. Mabugu,R.E. and Ntshingila, S.N., 2007. Domestic Water Use and Values in Swaziland: A Contingent Valuation Analysis.*Agrekon,*Vol 46, No 1

Green, D., Jakowitz, K.E., Kahneman, D., and McFadden, D., 1995. „Referendum contingent valuation, anchoring, and willingness to pay for public goods". A paper presented at the August 1995 World Congress of the Econometric Society, Tokyo.

Green, W.H., 2003. *Econometric analysis: International Edition*. 5th edition.Price Hall. New York. Griffiths, W.F., Hill, R.C., and Judge, G.G., 1993. *Leaning and practicing Econometrics.*John Willey and Sons, Inc. New York. 886 pp.

IUCN and PBWO.,2008. Scenario Report: The analysis of water allocation scenarios for the Pangani River Basin. Moshi, Tanzania: The World Conservation Union (IUCN) and Pangani Basin Water Office (PBWO).

Khanal, R.andPaudel, D., 2012.Payment for Ecosystem Services (PES) Schemes for Conserving Sardu Watershed Nepal: Existing Practices and Future Prospects.Technical Working Paper. 12p.

Lalika, M.C.S., Meire., P. and Ngaga, Y. M. 2015a. Exploring watershed conservation and water governance along the Pangani River Basin, Tanzania. *Land Use Policy* 48 (2015) 351–361

Lalika, M.C.S., Meire., P. Ngaga, Y. M. and Chang"a, L. 2015b. Watershed dynamics and climate change and climate variability along Pangani River Basin, Tanzania. *Ecohydrology and Hydrobiology,* 15 (1): 26 – 38. http://dx.doi.org/10.1016/j.ecohyd.2014.11.002

Lalika, M.C.S., Meire., P. and Ngaga, Y. M. 2015c. Paying to Conserve Watershed Services in Pangani River Basin Tanzania. In: Hipel, K, W, Fang, L., Cullmann, J. and Bristow, M. (eds.). "Conflict Resolution in Water Resources and Environmental Management".Springer (Heidelberg). Germany. ISBN 978-3-319-14214-2

Lalika, M.C.S., Meire., P. Ngaga, Y. M. Ngowi, S. E. and Schaafsma, M. 2014. Analyzing Ecosystem Services at Watershed Scale: Implications for Conservation in Upper Kikuletwa Sub-Catchment, Tanzania. In: Donke, M. (ed.), "Welcome to Africa: Climate Change Adaptation in Eastern Africa." 4 – 12 March, 2013, Khartoum / El-Obeid, Sudan. Edited and published conference proceedings: 204 - 223. ISBN 978-3-942934-03-9.

Lalika, M.C.S., de Deckere, E. and Ngaga, Y.M., 2011. Payment for Water Services as Basis for Natural Resource Management: Experience from Pangani Basin Tanzania. In: Anderson K., Okeyo-Owur, J.B. and Hezron, M. (eds), *Towards Implementation of Payment for Environmental Services (PES).*BOD Publishers, London. Pp 176-195.

Liquete, C., Maes, J., La Notte, A. and Bidoglio, G., 2011. Securing water as a resource for society: An ecosystem service perspective.*Ecohydrology and hydrobiology* 11 (3-4), 247 - 259

Locatelli, B.and Vignola, R., 2009.Managing watershed services of tropical forests and plantations: Can meta-analyses help? *Forest Ecology and Management* 258, 1864–1870 Long, S.J., 1997.*Regression Models for Categorical and Limited Dependent Variables*: Advanced Quantitative Techniques in the Social Sciences Series 7. SAGE Publications, London, UK. MEA., 2005.

Ecosystems and Human Well-Being: Synthesis. Millennium Ecosystem Assessment.Island Press, Washington, DC.

Mohamed, N., Shamsudin, M.N., Ghani, A.N.A., Radam, A., Khaffashi, S., Rahim, N.N.R.N.A., Hassin, N.H.B., 2012.Wilingness to Pay for Watershed Conservation at Hulu Lengat, Selanger.*Applies Sciences* 12(17), 1859 – 1864.

Mwamila, T.B., Kimwaga, R.J. and Mtalo, F.W., 2008. Eco-hydrology of the Pangani River downstream of NyumbayaMungu reservoir, Tanzania.*Physics and Chemistry of the Earth* 33, 8-13.

Ostrom, E., 1990. *Governing the Commons. The Evolution of Institutions for Collective Action.* Cambridge: Cambridge University Press.

Ostrom, E., Schroeder, L., and Wynne, S., 1993. *Institutional Incentives and Sustainable Development*.Westview Press, Boulder, Colorado, 264 pp.

Rosett, R.N., and Nelson, F.D. (1975).Estimation of the two-limit probit regression model. *Econometrica vol*. 43:141-146.

Samdin, Z., Abdul-Aziz, A., Radam, A. and Yakob, MR., 2010. Factors influencing the willingness to pay for entrance permit: The evidence from Taman Negara National Park. Institute of Tropical Forestry and Forestry Products (INTROP).*Sustainable Development.*Volume 3.

Sanga, G.J. Moshi, A. B. and Hella, J. P., 2013. Small Scale Farmers" Adaptation to Climate Change Effects in Pangani River Basin and Pemba: Challenges and Opportunities. *International Journal of Modern Social Sciences* 2(3), 169-194

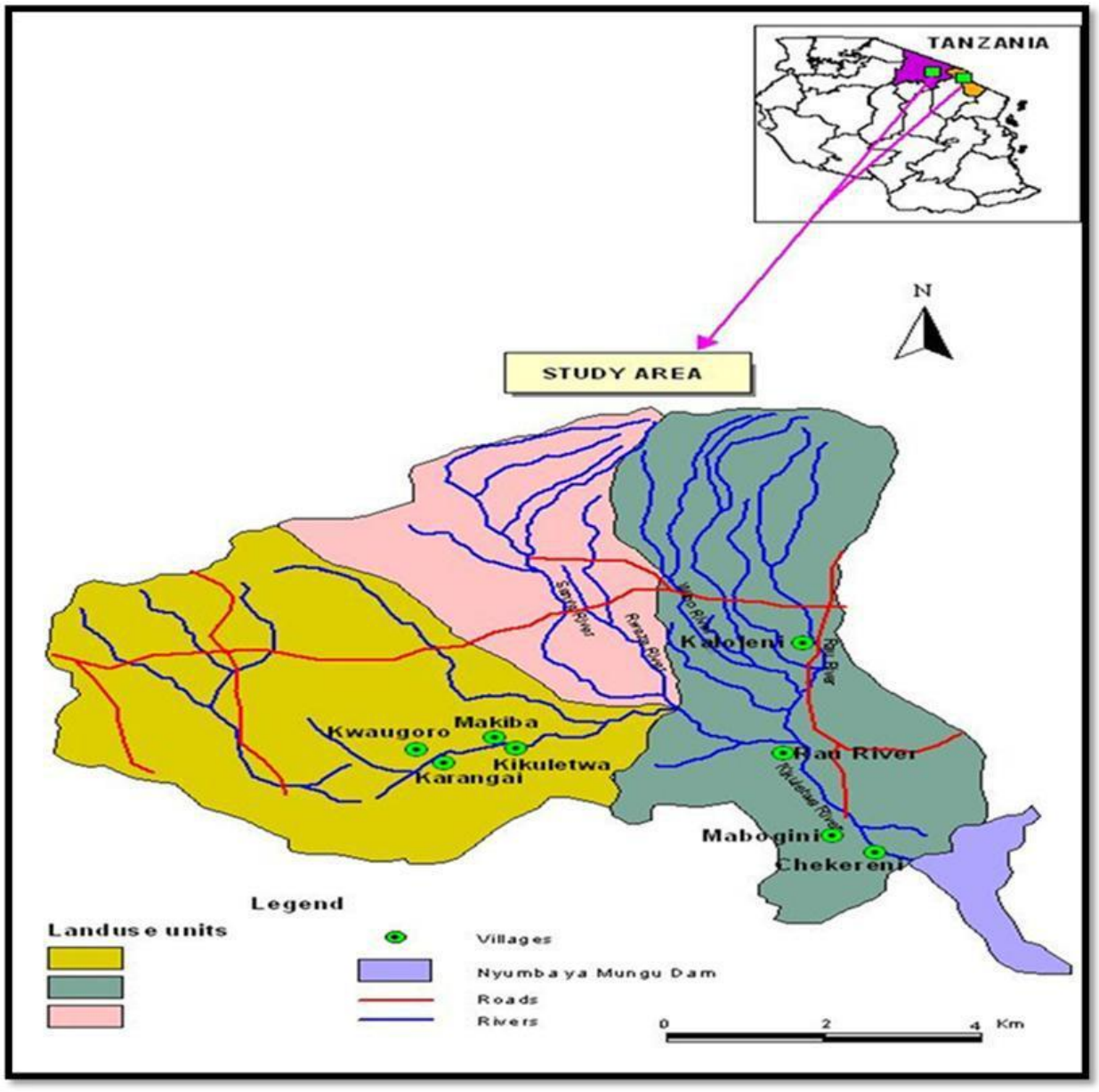
Stanton, T., Echavarria, M., Hamilton, K. and Ott, C., 2010. State of Watershed Payments: An Emerging Marketplace. Ecosystem Marketplace. http://www.foresttrends. org/documents/files/doc_2438.pdf [accessed March, 2013]

Tietenburg, T., 2002.Environment and Natural Resource Economics (Fifth Edition).Addison-Wesely. UK, pp 630

Turpie, J., Morais, C. and Blignaut, J.N., 2008. The working for water programme:
Evolution of payment for ecosystem services mechanisms that addresses both poverty and ecosystem services delivery in South Africa. *Ecological economics 65*, 788 - 798.
Whittington, D., 2002. Improving the Performance of Contingent Valuation Studies

Appendices

Appendix I: Figure 1: Location of the study area along Pangani River Basin, Tanzania



Appendix II: Table 1: Responses on perceptions on WTP for watershed conservation

Variable		Counts	Percentages
Contribution for conservation		(n=360)	
	Willing	286	79
	Not willing	74	21
		n=259	
Time frame for payment	12 months	136	37.8
	6 months	121	33.6
	1 month	2	0.6
		n=285	
Certainty about WTP	1-5 Very/certain	258	90.5
	6-10 Very/uncertain	27	9.5
		n=277	
Reasons for WTP	Dependency on water for household and irrigation uses	134	48.4
	Sustainable water flow for future generations	130	46.9
	Watershed conservation for flow of ES	8	2.8
	Conservation to enhance ecological processes	5	1.8
		n=345	
WTP for marginal conservation effects	Willingness to wait	269	78
	Unwillingness to wait	76	22

Appendix III: Table 2: Marginal probabilities for small holder farmer's willingness to pay for watershed services

Variable	Marginal probability ($\partial y / \partial x$)	Standard error	z	P (|z |>z)
Water use fee	-0.325e-06*	0.190e-06	-1.714	0.0866
Gender(1=female)	-0.166e-01	0.496e-01	-0.335	0.7380
Marital status (1=married)	0.135e-03***	0.038e-03	3.501	0.0012
Education level	-0.731e-02***	0.336e-01	-2.178	0.0263
Occupation	0.729e-01*	0.408e-01	1.787	0.0739
Household size	0.151e-01***	0.074e-01	2.036	0.0282
Number of hh members engaged in income generating activities	-0.295e-03*	0.161e-03	-1.831	0.0672
Total annual income	-0.923e-07***	0.334e-07	-2.762	0.0058
Irrigation income	0.450e-07**	0.234e-07	1.925	0.0505
Household water sources	-0.128e-03*	0.081e-03	-1.572	0.0946
Distance from the water sources	0.171e-03***	0.760e-04	2.247	0.0247
Amount of water from other sources	-0.112e-03	0.836e-04	-1.335	0.1819
Water used for cooking	0.207e-02	0.533e-02	0.388	0.6978
Water used for drinking	0.114e-01	0.294e-01	0.386	0.6997
Water used for washing clothes	0.205e-01	0.153e-01	1.342	0.1795
Water used for washing dishes	-0.357e-01	0.299e-01	-1.193	0.2330
Water used for toilets	0.144e-03	0.146e-03	0.988	0.3234
Price for water	-0.257e-05	0.932e-05	-0.276	0.7826
Total land size (ha)	-0.622e-04 ***	0.225e-03	2.761	0.0059
Amount paid for irrigation	0.180e-06 *	0.107e-06	1.684	0.0847
Yield with irrigation	0.102e-04*	0.581e-05	1.760	0.0685
Yield without irrigation	-0.152e-05	0.919e-05	-0.166	0.8683
Water use for irrigation	-0.218e-03*	0.143e-03	-1.522	0.0984
Number of observations (N) = 360				
Log Likelihood= -219.63367				
LRChi2=3.41964				
Prob-Chi2= 0.8238571e-04				

Appendix IV:Table 3: Maximum amount small holder farmer's WTP

Variable	Coefficient	Standard error	b/St.Er	P[|Z|>z]
Willingness to pay	22261.83038***	10520.5486	2.116	0.0183
WTP certainty	3.670318282**	1.9170822	1.915	0.0556
Water use fee	-3.05E-04	5.16E-03	-0.059	0.9528
Gender (1=female)	-6527.65341***	1465.0761	-4.456	0
Marital status	17.379702***	4.9702078	3.497	0.0005
Education level	4511.653016***	1594.595	2.829	0.0047
Occupation	172.3448633***	81.62695	2.111	0.0094
Household size	-121.119996*	67.44146	-1.795	0.0693
Number hh members engaged in income generating activities	1.442747865***	0.6407413	2.252	0.0217
Total annual income	1.36E-04***	6.56E-05	2.079	0.0098
Irrigation income	1.93E-04	6.66E-04	0.29	0.7719
Household water sources	-9.11648574**	4.7719495	-1.91	0.0561
Distance from the water sources	8.84E-02	2.1981903	0.04	0.9679
Amount of water from other sources	-6.32423857***	2.6047383	-2.428	0.0152
Water used for cooking	1.93E-04	6.66E-04	0.29	0.7719
Water used for drinking	419.3810105	791.71684	0.53	0.5963
Water used for washing clothes	870.0716956*	480.05976	1.812	0.0699
Water used for washing dishes	-12.2853168	10.825056	-1.135	0.2564
Water used for toilets	5.477136869	5.7441356	0.954	0.3403
Price for water	-1.01E-02	2.44E-01	-0.041	0.967
Total land size (ha)	1.557890715*	0.95378501	1.633	0.0743
Amount paid for irrigation	-3.78E-02***	1.48E-02	-2.557	0.0056
Yield with irrigation	0.617585859	2.71E-01	2.275	0.0187
Yield without irrigation	-9.54E-01*	6.17E-01	-1.545	0.1223
Water use for irrigation	-2.89293972	5.527303	-0.523	0.6007

Number of observations (N)=360
Log-L= -1290.48
Threshold values for the Model: Lower=.000 Upper=+∞
LM test [df] for tobit= 94.576
ANOVA based fit measure = 13.636318
DECOMP based fit measure = 0.473343

AN IMPACT-DRIVEN RESPONSE TO SOUTH AFRICA'S WATERCHALLENGES: CSIR'S WATER SUSTAINABILITY FLAGSHIP

H.H. Pienaar[1], M. Claassen[1], P. Hlabela[2] and K. van Breukelen[3]

[1]Council for Scientific and Industrial Research (CSIR), Natural Resources and Environment Pretoria, South Africa, email: hpienaar@csir.co.za; mclaassen@csir.co.za
[2]CSIR, Built Environment
Pretoria, South Africa, email: phlabela@csir.co.za
[3]CSIR, Consulting and Analytical Services Pretoria, South Africa, email: kvbreukelen@csir.co.za

Key words
(water quality, challenges, flagship, sustainability, solutions)

Topic of this work

Critical water challenges in South Africa are well recognized and documented. Available information indicate that large areas in South Africa experience 'water stress'. There is a worsening of water resource quality in many rivers with a deterioration of reservoirs and ecosystems and especially rural communities face growing risks of water shortages and the health impacts of contamination. Key initiatives to address these challenges have been considered by a number of role-players. However, a fragmented and isolated approach in responding to these water challenges is still evident, despite efforts by the Department of Water and Sanitation to realise a more holistic response (Fig. 1).

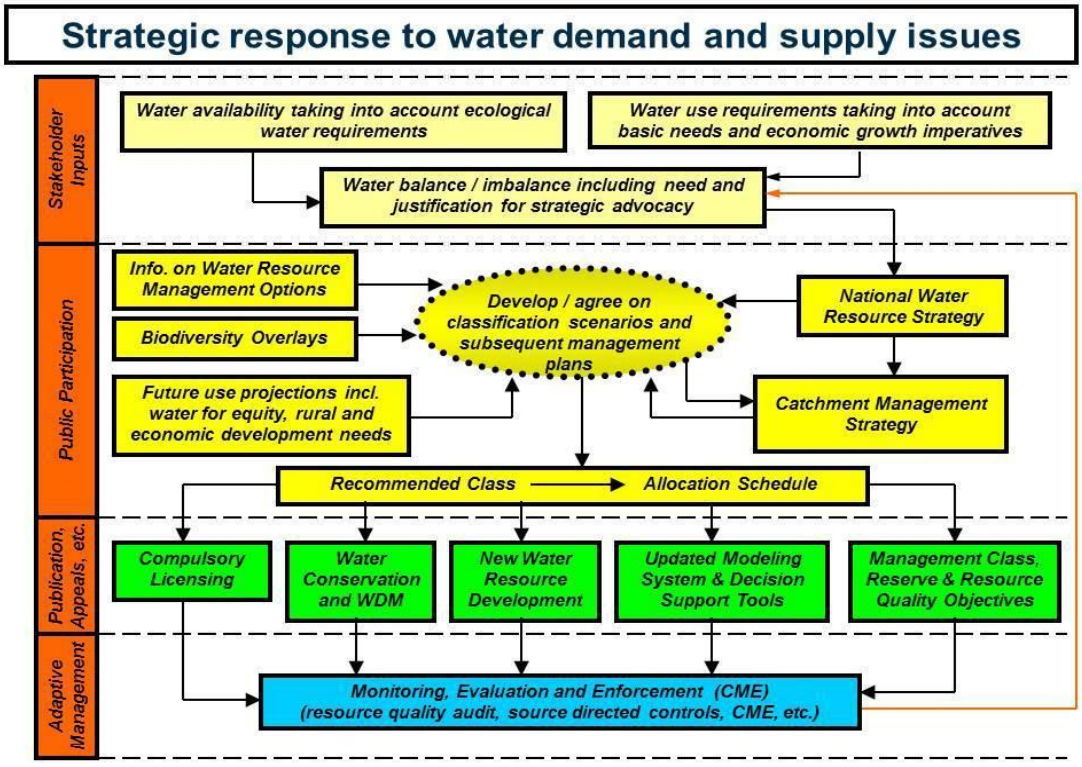


Figure 1: Strategic response to water quantity and quality problems

Operational application
The CSIR introduced its water sustainability flagship (WSF) programme, that is aimed at advancing a set of large-scale practical and effective science-based integrated solutions. The objective of the WSF is to contribute to the equitable, efficient and sustainable use of water to ensure that South Africa attains its national, social and economic growth and development aspirations.

Originality of this work
Through this WSF programme, three strategic clusters of interventions have been identified (in consultation with key stakeholders) to be addressed in an **integrated** manner, namely: water planning and governance tools, appropriate water infrastructure technology, and technologies for near-real-time monitoring. The novelty of this work lies in the integrated packaged solution of three interventions being applied concurrently to achieve one common objective, i.e. improvement in effluent water quality discharged from waste water treatment plants.

Data and method
Improvements in water sustainability will rely on an **integrated approach** where technological solutions and / or interventions for water infrastructure, planning and governance, as well as near real-time monitoring data and information are being addressed simultaneously. The aim is to achieve better water quality, less pollution and a decreased health risk in the regions where the implementation takes place.

Main results
The WSF programme addressed the abovementioned fragmentation in an integrated approach and initially focused on wastewater treatment with a strong emphasis on all the aforementioned three strategic clusters of interventions being identified. It successfully linked human settlement planning, technology and management options, and downstream user requirements to effectively manage wastewater and deliver water of good quality to support downstream social and economic development.

Impact of data and method application
CSIR researchers have completed an upgrade of the CSIR urban dynamics platform and software which can model future human settlement patterns at provincial level over a 30-year period and extend existing capabilities to make long-term water demand forecasts. Subsequent quantitative research investigations resulted in the development of policy and regulatory instruments to address inefficacies of municipalities to control the impact of the failing water treatment facilities.

Shortcoming of ineffective biodigesters at waste water treatment plants have been addressed thanks to automated processes that optimise temperature, pH levels and loading rates. Researchers have also designed a more affordable near real-time monitoring system which consists of sensing stations and software which is being tested at a district municipality's waste water plants. Water is pumped to a unit where probes test the pH, dissolved oxygen, conductivity and other parameters which could indicate deteriorating waste water quality. These readings are sent in real time via SMS to a CSIR surveillance point. Units have been installed at six waste water treatment plants, to take measurements every half an hour, which could provide a substantial improvement to current protocols at some plants in poorer resourced areas where water is monitored on a monthly basis or in critical cases, not at all.

Acknowledgements
All CSIR team members who made and / or are continuing to make a significant contribution to this initiative.

THE ECONOMIC VALUE OF CONJOINT LOCAL MANAGEMENT IN WATER RESOURCES: RESULTS FROM A CONTINGENT VALUATION IN THE BOQUERÓN AQUIFER (ALBACETE, SE SPAIN)

Carmen Rupérez-Moreno, Universidad Católica San Antonio de Murcia, UCAM, Murcia, Spain, email: carmen.ruperez@gmail.com
Julio Pérez-Sánchez, Universidad Católica San Antonio de Murcia, UCAM, Murcia, Spain, email:jperez058@ucam.edu
Javier Senent-Aparicio, Universidad Católica San Antonio de Murcia, UCAM, Murcia, Spain, email:jsenent@ucam.edu
Mª del Pilar Flores Asenjo, Universidad Católica San Antonio de Murcia, UCAM, Murcia, Spain, email:pflores@ucam.edu

Key words (*3.1)Water Framework Directive; conjoint management; water resources; local level; contingent valuation method.*

Topic of this work

The study presented in this work aims to provide an economic valuation of the benefits that would result from the conjoint local management of an aquatic ecosystem, namely the Boquerón aquifer in the municipality of Hellín (Albacete). It applies the contingent valuation method(CVM) within the framework established by the Water Framework Directive(WFD).Exploitation of the water resources in southeast Spain has proceeded without adequate control and has created a great risk to both the quantity and quality of water and a significant loss of ecosystems. The so-called Boquerón aquifer is especially important due to the fact that it supplies many of the town's irrigated areas and the town centre. Furthermore, associated with this formation, there is a series of springs, including Fuente de Isso. They are currently dried up from overexploitation.

Research question (or operational application)

The operational application is to elicit the total economic value (TEV) or total benefit that will be generated by managing the surface waters and groundwater conjointly of the Boquerón aquifer in order to recover its ecological status.The contingent valuation method is used to estimate the willingness of the citizens of the municipality of Hellín to pay for the proposed measures. In addition, econometricmodels have been used to determine the socioeconomicvariables (i.e., income, employment situation, green commitment, and educational level)that influence the willingness to pay in order to proposemeasures favouring the social acceptance of this type ofprojects.

Originality of this work

The results of this work could be used as a guide in the planning and integrated management of water resources. Moreover, the fact of including an economic analysis of environmental heritage features in projects of this type can be a means to justify investment of public money – which is particularly relevant in the difficult economic situation that Spain is currently facing. Furthermore, it can serve as a means to allow public participation.

Data and / or method

The phases in the design of a contingent valuation method are as follows: To determine concisely, in monetary terms, what is to be assessed, to define the target population, to establish the components of a hypothetical market, to design the questionnaire, and finally, to analyse and interpret the results.

Main results

The total benefits that it would be generated the conjoint management was € 187,464.36 per year. Moreover, because the CVM estimates both the use and non-use values of the environmental assets, the TEV can be decomposed into the sample of individuals who are users of the area above the aquifer and those who are not (Table 1).

Table 1. Willingness to pay of users and non-users.

		N	%	Mean	Std. Deviation
WTP	WTP users	33	19.18	35.88	47.31
	WTP non-users	139	80.82	14.86	20.27
	Total	172	100	18.89	28.63

The use value was €40,010 per year.The non-use value was estimated by multiplying the mean non-user WTP by the total target population, given that these non-use values can be enjoyed by the entire population by their mere existence and because they possess a legacy value for the future. The non-use value was €147,470 per year. This non-use value was much higher than the use value, and this feature justifies the application of CVM as a method of economic valuation of environmental assets, as it includes the non-use values.

Conclusion / Perspectives

From the results of the Logit and Tobit models – the probability of a positive WTP and the size of the green payment considered acceptable – it may be concluded that actions to improve the ecological status of the Boquerón aquifer by means of conjoint management at the local level would be acceptable to the inhabitants of Hellín. This is due to sociodemographic effects summarized by the income, employment situation and green commitment variables.In this study, according to the results, not all variables increase willingness to pay. The income variable has an inverse relationship to the WTP dependent variable because of the current economic crisis in Spain and increased environmental concern. This leads to wanting to participate in environmental improvement projects even if it means economic sacrifice for families with low incomes.

The results of the economic valuation of the non-use values of the environmental recovery of the Boquerón aquifer shows the importance of considering this method when assessing environmental assets of water resources. The CVM has the advantage of measuring the value of anything without the need for observable behaviour (data) and non-use values. The total benefits obtained reflect the approval of society with regard to making such improvements.

Acknowledgements

We are grateful to the respondents of the municipality of Hellín for participating in surveys of environmental economic valuation

.

The economic value of conjoint local management in water resources: Results from a contingent valuation in the Boquerón aquifer (Albacete, SE Spain)

Carmen Rupérez-Moreno[a], Julio Pérez-Sánchez[a], Javier Senent-Aparicio[a], M[a] del Pilar Flores-Asenjo[b]*

[a]*Department of Polytechnic Sciences, Universidad Católica San Antonio de Murcia, UCAM, Murcia, Spain*
[b]*Department of Social, Legal and Business Sciences, Universidad Católica San Antonio de Murcia, UCAM, Murcia, Spain*
*Corresponding author. E-mail address: carmen.ruperez@gmail.com (C. Rupérez-Moreno).

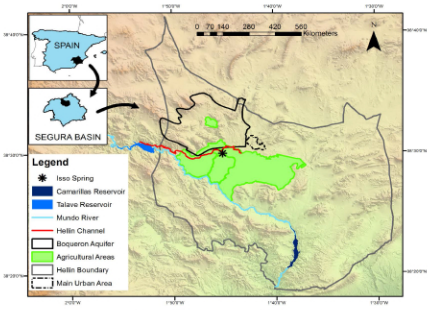


Fig.1. Location of Boquerón aquifer in Spain.

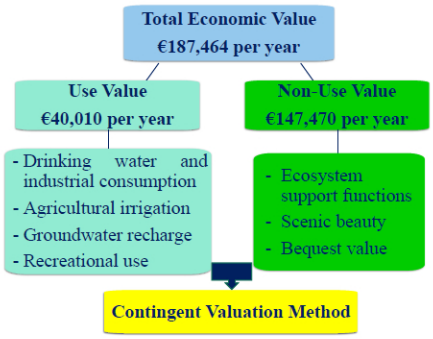


Fig.2. The Total Economic Value of the Boquerón aquifer groundwater.

Fig.3. Clusters according to WTP and sociodemographic variables.

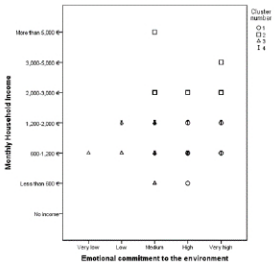


Fig.4. Relationships between Income and ECE

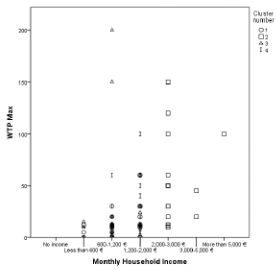


Fig.5. Relationships between WTP and Income

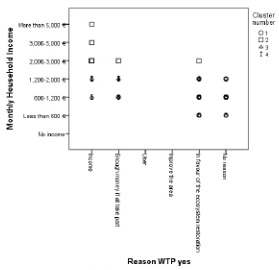


Fig.6. Relationships between Income and Reason WTP yes

Objectives:

- **To provide an economic valuation of the total benefits that will be generated by managing the surface waters and groundwater conjointly of the overexploited Boquerón aquifer in order to recover its ecological status.**
- **To improve the water use policy by encouraging the active involvement of stakeholders and consultation with the public.**

Methods:

Design of Contingent Valuation Method:

- To define the target population ➡ **9924 households and 240 surveys** by simple random sampling.
- To establish the hypothetical market ➡ **Willingness to pay (WTP)** and **vehicle payment** (an increase in the water bill over 1 year).
- To design the questionnaire ➡ **WTP (Yes/No)** to improve the ecological status of the Boquerón aquifer (Fig. 1) and the **maximum WTP** for the implementation of the proposed measures.
- Variables that could influence the variable WTP and the amount ➡ **Income, employment situation, and green commitment.**

Results and Discussion:

- The non-use value was much higher than the use value (Fig. 2).
- Each cluster was classified according to the WTP of the respondents and by sociodemographic variables with significant results (Fig. 3).
- Not all variables increase positively the WTP.
- The income variable has an inverse relationship to the WTP dependent variable (Figs. 4-6) because of the current economic crisis in Spain and increased environmental concern.

Conclusions:

- Conjoint use of water improves the environmental quality of aquifers.
- Willingness to pay would mean a 'financial sacrifice'.
- The environmental benefits were due to the high green commitment.

Acknowledgements:

We are grateful to the respondents of the municipality of Hellín for participating in surveys of environmental economic valuation.

PUBLIC SUPPORT FOR WETLAND RESTORATION: WHAT IS THE LINK WITH ECOSYSTEM SERVICE VALUES?

Samantha S. K. Scholte[1], Maya Todorova[2], Peter H. Verburg[1], Astrid J.A. van Teeffelen[1]

[1] Institute for Environmental Studies (IVM), VU University Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

[2] WWF Danube-Carpathian Programme, Ruse, Bulgaria

Keywords: values, ecosystem services, wetland restoration, conservation, attitudes

Topic and objectives

Fostering public support is essential for sustainable management and use of nature conservation areas, but restoration initiatives have mostly focused on restoring ecological functions without explicitly including values of the public. Similarly, the ecosystem service approach has predominantly been used to educate the public about the ecological and monetary importance of an ecosystem, neglecting what people themselves find important about ecosystems, i.e. the socio-cultural values of ecosystem services. To enhance public support for nature conservation it is crucial to broaden our scope beyond the ecological and economic domain and also devote attention to socio-cultural perspectives on the importance of ecosystem services. This paper explores how attitudes towards wetland restoration may be understood by looking at the socio-cultural values of ecosystem services. In addition we explore how such values can be explained by the awareness people have of ecosystem services and how they benefit from ecosystem services (in terms of resource dependency and recreational activities).

Originality

Few studies have tried to explicitly link wetland restoration attitudes with values for ecosystem services. Our results indicate that values for a particular type of ecosystem service (i.e. cultural, provisioning or regulating) may closely link to different motivations for wetland restoration. Our study emphasizes the importance to acknowledge a variety of motivations when gathering support for nature conservation, ranging from economic motivations to eco-centric motivations.

In addition, in many ecosystem services studies no clear distinction is made between the awareness of ecosystem services, i.e. the ability to recognize an ecological function as a benefit to you or others, and the values of ecosystem services, i.e. assigning importance to a particular ecosystem service. We hypothesize that these two do not necessarily coincide: a farmer may be aware of the flood regulating capacity of a wetland, but not consider it important for his own practices or livelihood. Our results indeed show that, although the two are closely linked, awareness and valuation of ecosystem services are not completely similar. Farmers and fishermen were more aware of regulating services than residents were, yet did not assign higher value to such services. Raising awareness about the importance of ecosystem services, to stimulate support for nature conservation, should go hand in hand with listening to people about their values for- and associations with- ecosystem services. When we gain better insight into

what ecosystem services are important to people, we can provide targeted information, thereby raising their awareness about the ecological functions that are necessary to sustain those services.

Data and Methods

We conducted face to face interviews in Persina Nature Park at the Lower Danube in Bulgaria, where several wetlands have recently been restored. We interviewed 102 local users, including farmers, fishermen and residents. We investigated values for fourteen ecosystem services, in different categories: (a) regulating services (ground water retention, climate regulation, water quality, flood regulation and soil erosion control), (b) provisioning services (production of food, production of materials, production of biomass for energy and production of medicines), and (c) cultural services (environmental education, existence values of biodiversity, recreation, tourism and aesthetic quality). We firstly asked people about their awareness and values for ecosystem services provided by Persina Nature Park. We used pictograms, depicting the various ecosystem services, and landscape photos to ask people if they could link ecosystem services to specific wetland types within Persina Nature Park. We assessed attitudes towards wetland restoration through statements, using a 3-point Likert scale, and used a principal component analysis to explore links between ecosystem service values and wetland restoration attitudes. Finally we created scatter plots, on the basis of the component scores for each respondent, to analyze differences between and within user groups.

Results

The provision of food was found most important as an ecosystem service. In addition cultural ecosystem services, specifically recreation and existence values for biodiversity, were also found important. Farmers and fishermen, who economically depend on provisioning ecosystem services provided by Persina Nature Park, also placed higher value on provisioning services than residents. Farmers and fishermen also placed higher value on cultural ecosystem services and they were more aware of regulating services than residents.

When asked to link the ecosystem services to specific wetland types, several differences appeared. Marshes and riparian forests were significantly less associated with aesthetic quality than meadows. At the same time however, marshes and riparian forests were associated more with biodiversity and wildlife than meadows. The provision of food and recreation were mentioned often when respondents were asked to think of Persina in general, but were mentioned less often when respondents had to link ecosystem services to the different wetland types.

Results from the principal component analysis unraveled four different components, i.e. attitude dimensions. The first dimension could be explained as a cultural perspective, with a focus on the importance of wetlands for people (both locally and distant) and the importance of cultural ecosystem services. The second dimension could be explained as supporting wetland restoration from an eco-centric perspective, with a focus on the importance of wetlands for plants and animals. The third dimension could be understood as viewing wetland restoration from an economic perspective. Appreciation of provisioning services correlated positively with this dimension, while appreciation of regulating services negatively correlated with this dimension. The economic perspective did not necessarily indicate a negative or positive attitude toward wetland restoration, but rather acknowledged a trade-off between economic prosperity and wetland restoration. In contrast, the final dimension demonstrated a more negative attitude

towards wetland restoration. There was no correlation with appreciation for ecosystem services for this dimension, suggesting that a negative perspective may go together with low values for all ecosystem services, i.e. seeing nature as providing no benefits.

REVIEW OF EH AND ES INTEGRATION AS AN INTERVENTION TOOL OF SPATIAL PLANNING FOR URBAN STREAMS

TEZER Azime

Istanbul Technical University, Faculty of Architecture, Urban and Regional Planning Department, Taskisla 34437 Taksim, ISTANBUL/TURKEY

tezera@itu.edu.tr

Key words: Urban streams, ecohydrology (EH), ecosystem services (ES), spatial planning, tools.

(3.5 Water related ecosystem services – case studies in the urban and rural contexts)

Abstract

Global urbanization trend is an inevitable outcome of rapid population growth in the world. The number of megacities, the size of urbanized regions, the share of population in urban areas have been increasing continuously, persistently and exponentially. Urban areas have been assumed as the main drivers of environmental pollution, natural resource depletion and habitat fragmentation while aiming to provide better quality of life for human societies on one hand, but also being in a clamp of degrading environment inevitably with its impacts. Depending on the degraded, depleted and imbalanced distribution of natural resources with the impacts of urbanization, the global assessments for urban areas have moved from a "parasite/consumer" since the early 1970's to a "hope" place after the dissemination of global sustainable development practices and policies released in recent decades. Freshwater ecosystems in urban areas have been going back and forth in these two ends. On the other hand, the concept of ecohydrology is representing a promising implementation policy for urban freshwater and coastal ecosystems for sustainable development as being a unifying concept between "the nature and the built" with its process oriented content to upgrade the condition of water resources without compromising ecological dynamics, ecosystem benefits to nature and society in urban areas. Additionally, ecohydrology represents a multi-disciplinary and multi-scale approach under the complex interaction of ecosystems, social and spatial dynamics for urban areas. Therefore this paper aims to identify the interaction between urban planning and ecohydrology to clarify common goals of both disciplines in urban streams.

4- Environmental monitoring and measuring of water-related natural processes

EFFECTS OF RIVER RESTORATION ON HYDRODYNAMIC PROCESSES AND VEGETATION COMPOSITION ON BRAIDED RIVERS :CASE STUDY:RIVER LECH, AUSTRIA

Barth Wolfgang, Egger Gregory, MuharSusanne;Institute of Hydrobiology and Aquatic Ecosystem Management (IHG); University of Natural Resources and Life Science, Vienna
wolfgang.barth@students.boku.ac.at

Key words

Lech, river restoration, floodplain, vegetation, hydrodynamic processes*(Topic 4.6)*

Introduction

The River Lech in Tyrol is often described as one of the rare, still remaining riverine landscapes in the Alpine region with relatively low human impacts. It is characterized bya dynamic bedload regime and extensive accumulation areas that particularly provide habitats for type-specific pioneer stages of riparian plant species (e.g.*Myricariagermanica*) and communities. The braided course in the upper reaches was partly straightened by river engineering measures in the past. The anthropogenic interventions led to negative ecological effects due to increased discharge in combination with less bedload input caused by bedload retention in the tributaries. River and floodplain habitats were functionally divided and dynamic processes were limited to the lower part of the river course. The designation of the Lech Valley as Natura 2000 site followed by the Life-Nature project „Wild riverine landscape of the Tyrolean Lech“, was the result of a rethinking process in the last decades. In addition to preserving the remaining near natural and dynamic river sections the project aimed at stoppingriverbed degradation and restoring anthropogenically modified river sections.

Our study investigates the effects of the restoration measures of the Life projectthat were implemented between 2002 and 2006, focusing on the floodplain vegetation and the change of hydrodynamic processes. Therefore pre- and post-monitoringdata were compared (Egger et al., 2007).

This work intends to demonstrate the short- and intermediate-term effects of therestoration measures regarding both the change of vegetation composition as well as the change of hydrodynamic processes at the river section*Weißenbacher Au* at the river Lech.

Methods

There are numerous restoration measures which have been initiated in the recent years to ecologically and morphologically improve rivers based on self-dynamic development. A new conceptual approach for analyzing the interrelationship among plant succession, hydromorphological impacts was used for the evaluation of the restoration project. The approach considers three process types with different succession phases: **the metastable process** (initial-, pioneer- and shrub phase), **the oscillation process** (herb-, shrub-, early successional woodland- and established forest phase) and **the acyclic process** (pioneer-, early successional woodland-, established forest- and climax phase). These processes describe the relationship between vegetation succession/retrogression and the impact of

disturbances. The metastable process describes the equilibrium between disturbance intensity and resistance of the plants while for the oscillation processdisturbance intensity and resistance are not in equilibrium. For theacyclic process disturbance intervals are longer than recovery time of the plants which leads to succession and maturation stage (Formann et al., 2013).

The comparison regardingriparian and floodplain vegetation types was based on high-resolution aerial photos, where homogenous structures were defined. In a second step thesedata from desktop analyses were verified and completed in situ.The comparison of the short-term effects in 2006 and the intermediate-term effects in 2014 for the vegetation is based on area balances of the different vegetation types.

Results

Figure 1demonstrates the percentage area of the succession stages compared to the total area (100%) of one of the investigatedriver sections(*Weißenbacher Au*).The removal of a groin was followed by an increase of the disturbance regime in 2006, hence a shift from the metastable-/ oscillation process and oscillation process to the metastable process (initial phase)was the result (EGGER et al., 2007). The situation in 2014 demonstrates a distinct increase of the areascharacterized by oscillation process (early successional woodland) of more than 18 % compared to 2006. This development can be explained by a change of the river dynamic due to the removal of a part of a riprap at the opposite site of the main flood plain after completion of the Life project in 2006. The graph also demonstrates a stable acyclic process with almost no alteration over all observed years.

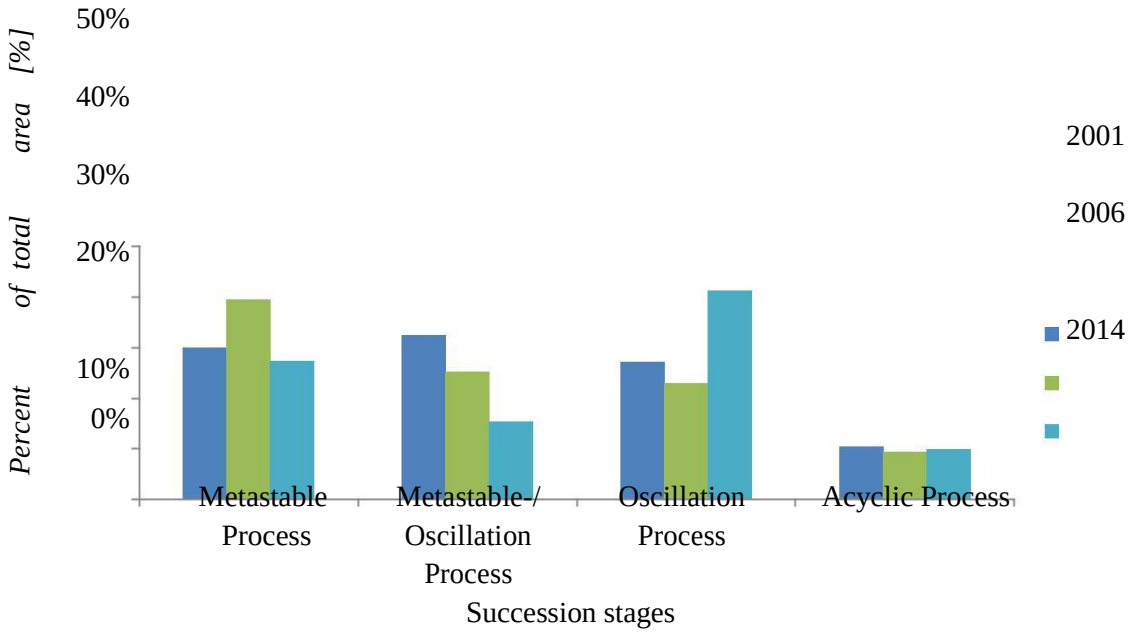


Figure 1: Distribution of the different succession stages in percent of the considered area (30 ha) in the *Weißenbacher Au* in 2001, 2006 and 2014.

The area balances of the vegetation types demonstrates a continuing increase of the area of waterbodies with the maximum in 2014 (6.28 ha). At the same time river bank structures without vegetation decreased in 2014 (7.38 ha) compared to 2006 (10.37 ha). Pioneer vegetation had the maximum area in 2001 (3.05 ha) before the Life project whereas after completion of the project the area of pioneer vegetation was very low with 0.65 ha in 2006 and 0.71ha in 2014.

Conclusion

One target of the Life-Nature project „Wild riverine landscape of the Tyrolean Lech“was to restore river sections influenced by anthropogenic interventionsto reestablish dynamic processes.There was an increase of hydrodynamic processes immediately after completion of the Life project in 2006 but against the expectation the intermediate-term data showed a decrease of dynamic processes in 2014. The decrease of areas of bank structures without vegetation and pioneer vegetation underline this development. Fewer disturbance events tend to support stable vegetation structures. To evaluate all effects of river restoration at the river Lechalso long-term data will be needed in the future.

References

Egger, G.; Aigner, S.; Angermann, K. (2007): Vegetationsdynamik einer alpinen Wildflusslandschaft und Auswirkungen von Renaturierungsmaßnahmen auf das Störungsregime, dargestellt am Beispiel des Tiroler Lechs. In: Jahrbuch des Vereins zum Schutz der Bergwelt (München), Vol. 72, pp. 5-54.

Formann, E.; Egger, G.; Hauer, C.; Habersack, H. (2013): Dynamic disturbance regime approach in river restoration: concept development and application. In: Landscape and Ecological Engineering 10 (2), pp. 323– 337.

ECOHYDROLOGY' 2015, LYON, FRANCE, 21 TO 23 SEPTEMBER

Effects of River Restoration on Hydrodynamic Processes and Vegetation Composition on Braided Rivers

Case Study: Lech River, Austria

Wolfgang Barth, Gregory Egger, Susanne Muhar

Institute of Hydrobiology and Aquatic Ecosystem Management (IHG);
Department of Water - Atmosphere - Environment (WAU);
University of Natural Resources and Life Sciences, Vienna

University of Natural Resources and Life Sciences, Vienna

Background:

The Lech River in Tyrol is often described as one of the rare, still remaining riverine landscapes in the Alpine region with relatively low human impacts. The braided course in the upper reaches was partly straightened by river engineering measures in the past. These interventions led to negative ecological effects due to increased discharge in combination with less bedload input caused by bedload retention in the tributaries. River and floodplain habitats were divided functionally and dynamic processes were limited to the lower part of the river course. Our study investigates the effects of the restoration measures of the Life project that were implemented between 2001 and 2006, focusing on the floodplain vegetation and the change of hydrodynamic processes [Fig. 4-6]. Therefore pre- and post-monitoring data were compared.

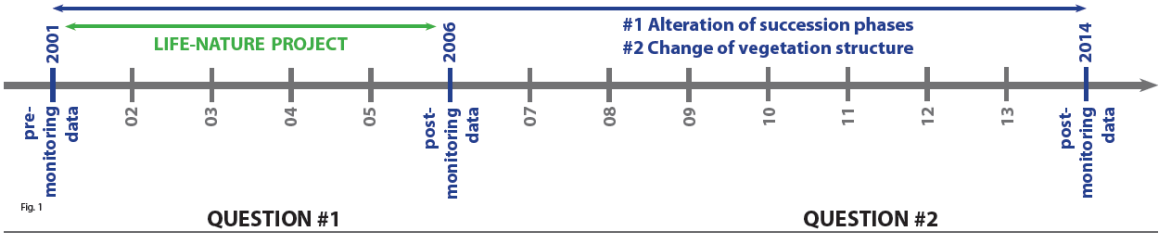


Fig. 1

QUESTION #1

What are the short- and intermediate-term effects of the restoration measures concerning vegetation succession and retrogression?

Method:

A new conceptual approach for analyzing the interrelationship among plant succession and hydromorphological impacts was used for the evaluation of the restoration project. The approach considers three process types with different succession phases [Fig. 1-2]: **the metastable process** (initial-, pioneer- and shrub phase), **the oscillation process** (herb-, shrub-, early successional woodland- and established forest phase) and **the acyclic process** (pioneer-, early successional woodland-, established forest- and climax phase). These processes describe the relationship between vegetation succession/retrogression and the impact of disturbances[1].

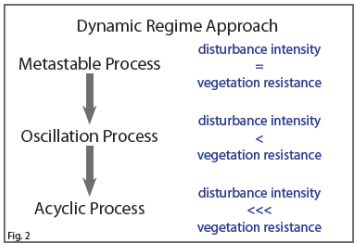


Fig. 2

Results:

The removal of a groin was followed by an increase of the disturbance regime in 2006, hence a shift from the metastable-/ oscillation process and oscillation process to the metastable process (initial phase) was the result[2]. The situation in 2014 demonstrates a distinct increase of the areas characterized by the oscillation process (early successional woodland) of more than 18 % compared to 2006. This development can be explained by a change of the river dynamics due to the removal of a part of a riprap at the opposite site of the main flood plain after completion of the Life project in 2006 [Fig. 3].

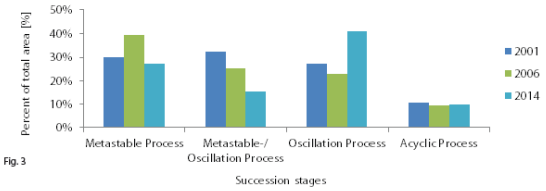


Fig. 3

QUESTION #2

What are the short- and intermediate-term effects of the restoration measures concerning the floodplain vegetation structure?

Method:

The comparison regarding riparian and floodplain vegetation types was based on high-resolution aerial photos, where homogenous structures were defined. In a second step these data from desktop analyses were verified and completed in situ. The comparison of the short-term effects in 2006 and the intermediate-term effects in 2014 for the vegetation is based on area balances of the different vegetation types [Fig. 1].

Fig. 4 July 2014

Fig. 5 Aug. 2014

Fig. 6 Sept. 2014

Results:

The area balances of the vegetation types demonstrates a continuing increase of the area of waterbodies with the maximum in 2014 (6.28 ha). At the same time river bank structures without vegetation decreased in 2014 (7.38 ha) compared to 2006 (10.37 ha). Pioneer vegetation had the maximum area in 2001 (3.05 ha) before the Life project whereas after completion of the project the area of pioneer vegetation was very low with 0.65 ha in 2006 and 0.71 ha in 2014 [Fig. 7-10].

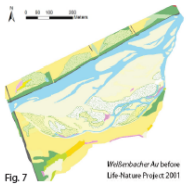


Fig. 7 Weißenbacher Au before Life-Nature Project 2001

Fig. 8 Weißenbacher Au after Life-Nature Project 2006

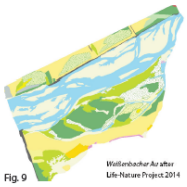


Fig. 9 Weißenbacher Au after Life-Nature Project 2014

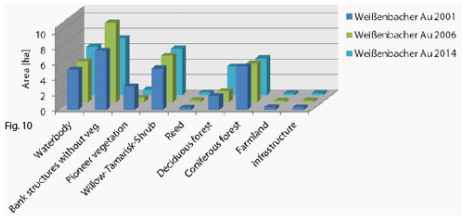


Fig. 10

Discussion and Conclusion:

One target of the Life-Nature project „Wild riverine landscape of the Tyrolean Lech" was to restore river sections influenced by anthropogenic interventions to reestablish dynamic processes. There was an increase of hydrodynamic processes immediately after completion of the Life project in 2006 but against expectations the intermediate-term data showed a decrease of dynamic processes in 2014. The decrease of areas of bank structures without vegetation and pioneer vegetation underline this development. Fewer disturbance events tend to support stable vegetation structures. To evaluate all effects of river restoration at the Lech river also long-term data will be needed in the future.

References:

[1] Formann, E.; Egger, G.; Hauer, C.; Habersack, H. (2013): Dynamic disturbance regime approach in river restoration: concept development and application. In: Landscape and Ecological Engineering 10 (2), pp. 323–337.

[2] Egger, G.; Aigner, S.; Angermann, K. (2007): Vegetationsdynamik einer alpinen Wildflusslandschaft und Auswirkungen von Renaturierungsmaßnahmen auf das Störungsregime, dargestellt am Beispiel des Tiroler Lechs. In: Jahrbuch des Vereins zum Schutz der Bergwelt (München), Vol. 72, pp. 5-54.

ASSESSMENT OF THE OCCURRENCE OF MARINE PHARMACEUTICAL POLLUTANTS IN THE SEMI-ARID MEDITERRANEAN CONTEXT USING BIOASSAY SYSTEMS AND CHEMICAL IDENTIFICATION

Leyla Tahrani, YosraAyari, Tim Ryns, Van Loco, Luc Verschaeve[c]Hedi Ben Mansour

[a]Higher Institute of AppliedSciences and Technology Mahdia Monastir University Tunisia
[b]Laboratory of Chemical Residues and Contaminants; Direction of Food Medicines and Consumer Safety; Scientific Institute of Public Health; Juliette Wytsmanstraat 14; Brussels 1050; Belgium.

[c]Laboratory of toxicology, Scientific Institute of Public Health; Juliette Wytsmanstraat 14; Brussels 1050; Belgium.
hdbenmansour@gmail.com

Keywords: Marine pollution, antibiotics, bio-monitoring, WWTPs, LCMS/MS, genotoxicity,

Topic of this work
Topic 4: Environmental monitoring and measuring of water-related natural processes

This study describesfirst the development and validation of a rapid, sensitive and accurate method for the simultaneous determination of 56 antimicrobial drugs (tetracyclines, sulfonamides, β-lactams, macrolides and quinolones) in environmental and waste water using ultra-performance liquid chromatography- tandem mass spectrometry (UPLC-MS/MS). The analysis revealed a critical contamination in aquatic surface and the amounts were between 1 ng mL^{-1} and 647 ng mL^{-1}inpharmaceutical effluent and WWTPs.In the other hand, we opted, in this work, to seek pharmaceutical residues in fish collected in different coastal areas of Tunisia. Chemical analysis using UPLC-MS-MS showed the presence of a variety of antibiotics such as sulfacetamide, norfloxacin, oxacillin, flumequineandoxtétracyclines. The impact of these antibiotics on marine organisms has been studied by performing histological sections of gills and digestive tracts of wild Mediterranean mussel *Mytilusgalloprovincialis* exposed in vitro to different concentrations of pharmaceutical effluents. A large pathological power was revealed on the digestive glands and gills this activity is dose-dependent.A genotoxic study was performed by Vitotox test, comet assay and micronuclei test (MN). Results showed that the all WWTPs influents were genotoxic (the genotoxicity was ≥ 40% with the comet assay and the number of binuclear cells with micronuclei was ≥ 12‰ in comparison with the negative control 4‰), the 75% of WWTPs effluents were also genotoxic (genotoxicity was ≥ 20 % for the comer assay and the number of binuclear cells with micronuclei was < 8 ‰). The neutral red uptake test showed no toxicity for all water samples.

IN CHANNELWOOD RAFT AND ICE COVER MONITORING USING AUTOMATIC PROCESSING GROUND IMAGERY

Véronique Benacchio, UMR5600 – EVS, Université de Lyon, veronique.benacchio@ens-lyon.fr
Hervé Piégay, Thomas Buffin-Bélanger, Lise Vaudor, Kristell Michel

Key Words: Ground imagery; image processing; large datasets; wood raft; ice cover.

Topic of this work

This study explores the potential of ground imagery and automatic cameras as a tool for monitoring river dynamics, especially processes not yet explored because acting occasionally and at times difficult to predict. Two examples will be presented to show how ground imagery can be used to monitor such processes. The first one is the assessment of the wood flux from the upstream Rhône River catchment (France), monitoring the wood raft dynamics in the Genissiat dam reservoir. The second one is the characterization of the ice cover set up and break up in a meander of the Saint Jean River (Gaspésie, Québec) during winter.

Research question (or operational application)

In riverine sciences, ground imagery presents numerous advantages and seems to be complementary with satellite and aerial imagery, but also with field observation and measurements. This tool has a potential to improve the knowledge of stream processes allowing to detect feature changes (e.g., characteristics of water surface or water column and neighboring units), to realize measures with high temporal frequency (until 10 to 20 images per second for video monitoring) and over long periods. With this study, we would like to define the potentials but also the limits of automatic cameras to monitor streams. The aim is to develop a method that is simple and repeatable to study various fluvial processes which can be detected from a set of images.

Originality of this work

In the field of riverine sciences and notably geomorphology, ground imagery is used since the beginning of the 2000. Until now, most of the dataset were extracted from visual observations and measures were realized manually. But large amounts of valuable data are produced and their visual analysis is very time consuming and cannot permit to provide real-time survey. So we tried to develop a method to automate image processing in order to maximize exploitation of the whole datasets, get a time series which is more detailed and open issues for developing real-time monitoring systems.

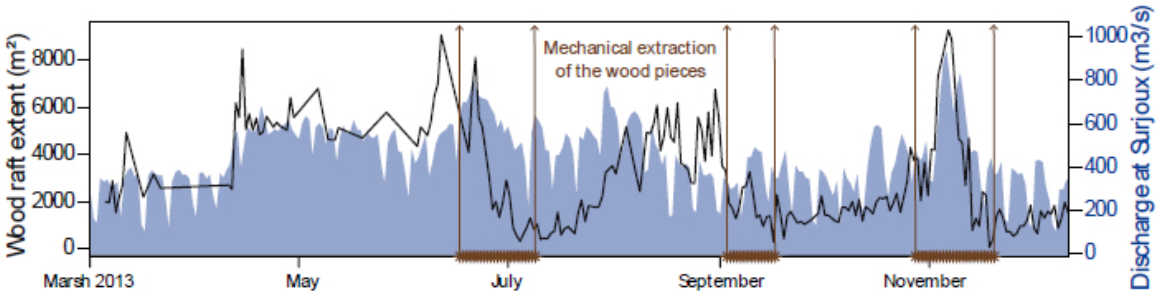
Data and / or method

We worked on two datasets acquired with automatic ground cameras. The first one shoots the Genissiat dam reservoir (Rhône River, France) with a frequency of 10mn. We survey here a wood raft which grows up through time and is mechanically extracted 3 to 4 times per year. The second one is acquired on the Saint-Jean River (Gaspésie, Québec) with a 1 hour frequency. We observe here the ice

cover set up and break up. These datasets were mainly processed under the R software. The same methodological protocol was applied on both of them. It is based on an automatic classification of the pixels of images thanks to a random forest algorithm. Images of the Genissiat dataset were georectified in order to allocate to each pixel a surface proportional to its real surface.

Main results

The method provides a classification rate of about 97% for the Genissiat dataset and about 94% for the Saint Jean dataset. The graphic hereunder shows a part of the time series obtained after processing of the Genissiat dataset from March to December 2013. The correlation between the wood raft surface increases and the Rhône River peaks is quiet well established. This is notably the case for the flow peaks of November or August and the high flows of April whereas the wood peak of June seems not really being linked to any floods or high flows. Moreover the period during which wood is arriving to the reservoir is also variable, very abrupt in April and November (just a few days), but much slower in July (about 20 days). As shown with this example, such series is useful to establish a wood discharge, and explore its temporal pattern related to peak flow characteristics and notably its catchment origin, as well as other potential driving factors.



Time series of the wood raft predicted in the Genissiat dam reservoir (black line) and hydrological series of the Rhone River (blue area) 3.7km downstream from the dam (Surjoux gauging station) from Marsh 2013 to Dec. 2013 – Brown periods are periods during which wood is extraction mechanically from the reservoir.

Data and / or method

This work demonstrates that it is possible to monitor some river processes using high frequency ground imagery. This information is important for both scientists and practitioners. In-channel wood is known to be valuable for aquatic ecology but it is also a problem for hydraulic structures so it has to be managed carefully and there is an urgent need to understand its flux which is still unknown on most of the catchments because of lack of monitoring method. The river ice dynamics leads to important modifications of the flow in rivers during winter and the break up produces an increase in flood magnitude, bank erosion and damages of structures. Understanding how such process occurs as well as when it occurs is particularly important. If this technique is available in real-time, river managers could be informed downstream of the break up and anticipate risk situations.

Aknowledgements: We would like to thank the UMR 5600 – EVS (ISIG platform of ENS of Lyon), the Université Lumière Lyon II, the doctoral school ED483, the Université du Québec à Rimouski (UQAR), the SedAlp project and the Région Rhône-Alpes for their financial and/ or material support.

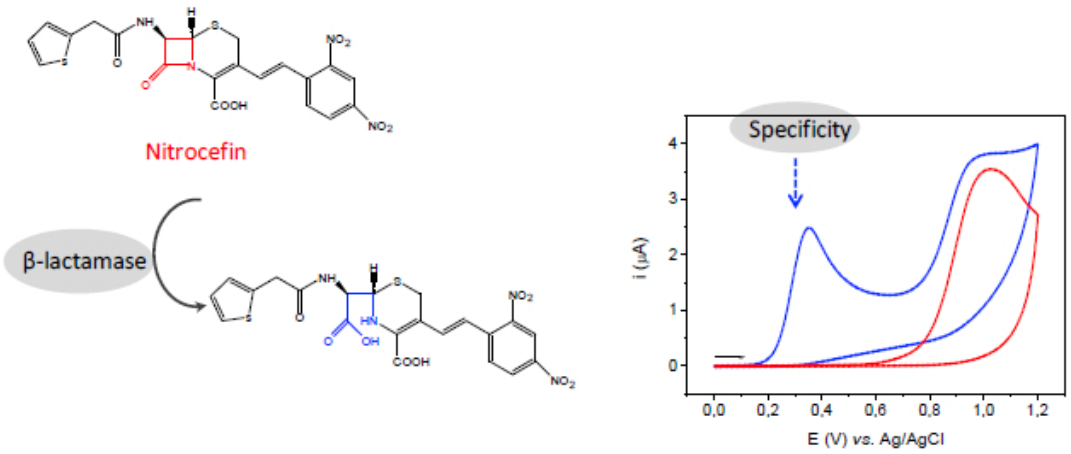
AMPEROMETRIC DETECTION OF EXTENDED-SPECTRUM B-LACTAMASE PRODUCING - ESCHERICHIA COLIIN WASTEWATER SAMPLES

B. Chantemesse, Université Bourgogne Franche-Comté, UMR1347 Agroécologie, 17 rue Sully, 21000 Dijon, France benoit.chantemesse@dijon.inra.fr
L. Betelli, Université Bourgogne Franche-Comté, UMR1347 Agroécologie, 17 rue Sully, 21000 Dijon, France laetitia.betelli@u-bourgogne.fr
A. Hartmann, INRA, UMR1347 Agroécologie, 17 rue Sully, 21000 Dijon, France alain.hartmann@dijon.inra.fr
F. Vienney, Université Bourgogne Franche-Comté, UMR1347 Agroécologie, 17 rue Sully, 21000 Dijon, France fabienne.vienney@u-bourgogne.fr
M. Rochelet, Université Bourgogne Franche-Comté, UMR1347 Agroécologie, 17 rue Sully, 21000 Dijon, France murielle.dequaire@u-bourgogne.fr

Sub-topics (4.1) and (4.3) :Antibiotic resistance, extended-spectrum β-lactamase, electrochemical sensors,nitrocefin, wastewater analysis

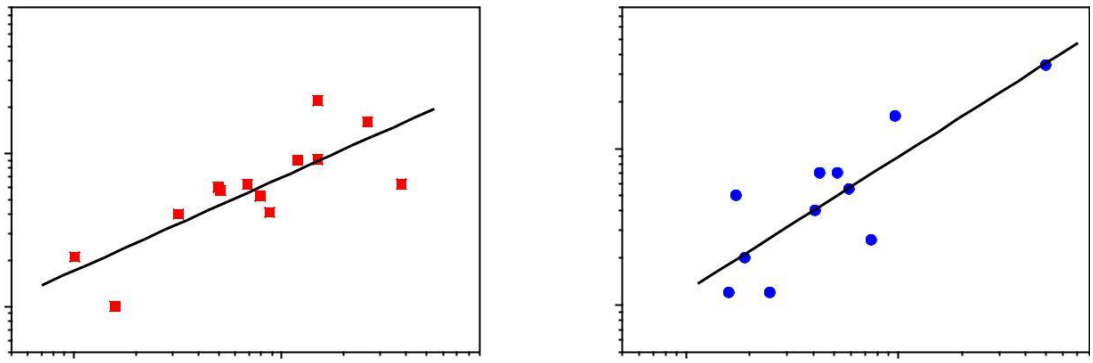
The emergence and dissemination of extended-spectrum β-lactamase (ESBL) -harboring *Enterobacteraceae*are well established as clinical problems that affect human and animal health. Several reports have shown that ESBL producing *Escherichia coli* (*E. coli*) strains are present in various effluents, such as hospital effluents discharge, inflow effluent to a wastewater treatment plant and outflow-treated effluent from a wastewater treatment plant. Though quantitative data are scarce, they would be useful to clearly evaluate the determinants of the spread of ESBL producing*E. coli* in natural environments. Therefore, rapid and convenient assays are highly desired for their enumeration in the wastewater network.

To reach this goal, we developed an amperometricmethod for the detection of the ESBL activity in wastewater samples with disposable carbon screen-printed sensors using the Nitrocefin, a commercially-available β-lactamase chromogenic substrate. As shown below, during the hydrolysis of the β-lactam ring, the Nitrocefin substrate is converted into a catalytic product which specific oxidation peak (~ + 0.2 V *vs*. Ag/AgCl) was selected as the analytical response to monitor the β-lactamase activity.



Nitrocefin can be hydrolyzed by all known β-lactamases produced by any bacteria, a specific two-step assay was developed for the detection of ESBL-producing bacteria in wastewater samples :(1) the subculturing of samples in the presence of cefotaximesupplemented or not with the potassium clavulanate (ESBL inhibitor) for a few hours followed by, (2) the incubation of each subculture filtrate with the Nitrocefinsubstrate which hydrolysis was monitored by amperometry. i_{Cef} and i_{Clav} correspond to the intensity of the anodic current measured (~ + 0.2 V *vs*. Ag/AgCl) for the sample incubated with the cefotaxime in the presence or not of potassium clavulanate, respectively. The value $i = i_{Cef} - i_{Clav}$ was calculated to assess the amount of EBSL *E. coli*producersby using calibration plots.

Thisamperometric assay was applied to the quantification of ESBL producing *E.coli* in raw and treated wastewater samples from different treatment plants in Côte d'Or. ESBL producers were detected in all of the analyzed samples and theresults were correlated to the colony amount estimated on agar plates containing Drigalsky medium supplemented with cefotaxime. As shown hereafter, the slope of the regression straight lines between the amperometric measurement and the ESBL producers enumeration is below 1with values ranging from 0.61 to 0.87 for the raw (red squares) and the treated (blue circles) wastewaters, respectively.Though further analyses are still required, complementary results indicate that the underestimation observed with the electrochemical protocol may be explained by the considerable diversity of genotypes among ESBL producers (i.e., the ESBL activity per culturable*E. coli* strain may strongly vary).



Owing to its low cost, portability, simplicity and its ability to perform measurements in turbid mediawithout isolation of the strain, this amperometric assay (4-5 h) which is considerably less time consuming then the culture-based method (24h00) holds great promise for the rapid quantification of ESBL producing *E.coli* in the wastewater networks and in other types of water samples (rivers, marine waters…).

Acknowledgements

This work was supported by the ConseilRégional de Bourgogne. We are also very grateful to Mrs Jessica Claire and MrSébastienSolanasfor their technical assistance.

FUNCTIONAL RESTORATION OF A RHINE ANASTOMOSING CHANNEL: HISTORICAL EVOLUTION, FIRST RESULTS CONCERNING HYDROMORPHOLOGICAL MONITORING AND THERMAL INFRARED (TIR) REMOTE SENSING SURVEY

David Eschbach [1], Laurent Schmitt[1], Guillaume Piasny[1], Laurent Pfister[2], Michèle Trémolières[3], Jean-Nicolas Beisel[4], Pascal Finaud-Guyot[5], Sylvain Weill[6], Sylvain Payraudeau[6], Gwenaël Imfeld[6], Pierre Grussenmeyer[7], Etienne Supper[7]

[1]LIVE, UMR 7362 - Unistra - CNRS - ENGEES, Faculté de Géographie et d'Aménagement, 3 rue de l'Argonne, 67083 Strasbourg
[2]Luxembourg Institute of Science and Technology, 41, rue du Brill, L-4422 Belvaux
[3]LIVE, UMR 7362 - Institut de Botanique, 28 rue Goethe, 67083 Strasbourg
[4]LIVE, UMR 7362 - ENGEES, 1 Quai Koch, 67067 Strasbourg
[5]ICube, UMR 7357 - Équipe Mécanique des Fluides, Département Mécanique, 2 rue Boussingault, 67000 Strasbourg
[6]LHyGES, UMR 7517 - Unistra - CNRS - EOST, 5 rue René Descartes, 67084 Strasbourg
[7]ICube, UMR 7357 - Équipe TRIO, Photogrammétrie et géomatique, INSA de Strasbourg, 67084 Strasbourg

Key words : Functional restoration, Rhine anastomosing channel, hydromorphological monitoring, airborne infrared remote sensing

Introduction

The Upper Rhine is one of the most altered hydrosystem in Europe. Ninety percent of its floodplain has been converted to arable and industrial areas (Schneider, 2011). Restoration projects conducted for three decades aims to achieve different objectives: (1) ecological enhancement, (2) flood control, (3) groundwater protection and (4) development of recreational areas.

The Rohrschollen artificial island, which is a Natural Reserve, is located 8 km south-eastern the city of Strasbourg and results of several engineering works that have been implemented since the mid-19th century (fig.1-a) such as correction and canalization. As a consequence, the main watercourse of the island, an anastomosing channel called "Bauerngrundwasser", is upstream disconnected (fig.1-b).

On the old-Rhine, an agricultural dam was built in the 1984 to raise groundwater level and allow flood retention during high flows. Hence, water level was extremely stable on the Bauerngrundwasser, discharge was very weak (less than 0.1 $m^3.s^{-1}$) and lack of floods induced clogging in the channel. In this context, aquatic and riparian habitats were drastically impacted and alluvial species of the island were declining.

The LIFE+ project "Restauration de la dynamique des habitats alluviaux rhénans sur l'île du Rohrschollen", managed by the city of Strasbourg, aims to restore hydromorphological and ecological processes such as bedload transport, channel dynamics, surface water-groundwater exchanges and renewal of pioneer ecosystems. In order to reach these objectives, the anastomosing channel has been reconnected to the Rhine by a floodgate and a new 800 meters long upstream channel. Water inputs, depending on the discharge of the Rhine (fig.2), range between 2 and 80 $m^3.s^{-1}$. A scientific monitoring

based on hydraulics, hydrology, fluvial morphology, hydrogeology and ecology has been implemented to assess the effectiveness and the sustainability of the restoration measures.

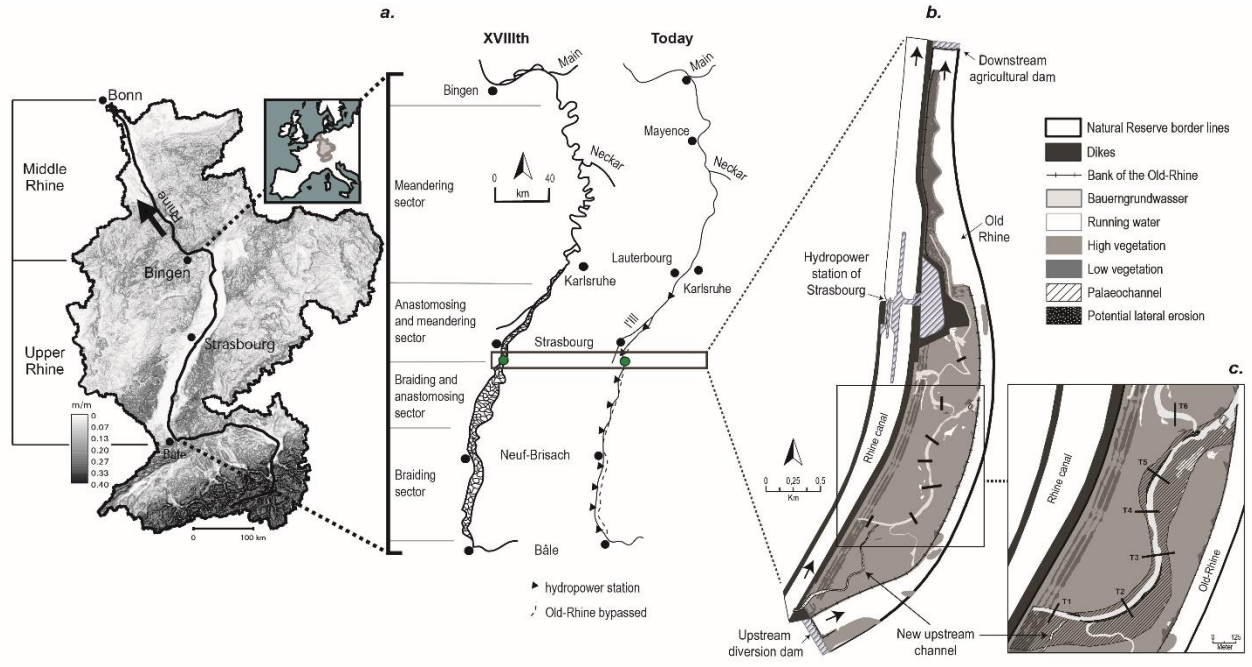


Fig.1 – a- Location of the Upper Rhine basin with a sectorization based on its channel pattern (Schmitt et al. 2009), river course evolution from the 18th century to nowadays and location of the study site. b- Map of the Rohrschollen Island. c- Lateral extension of the Rhine's palaeochannel and spatial extend of the potential lateral erosion areas (cf. results).

This study aims to present: (i) the long term trajectory of the hydrosystem, which is useful for the evaluation of the post-restoration evolution; (ii) the initial state based on a two-years pre-restoration monitoring; (iii) the first post-restoration hydromorphological results; (iiii) the first results of thermal infrared (TIR) remote sensing and scientific perspectives concerning the modelling of several compartments of the hydrosystem.

Material and methods

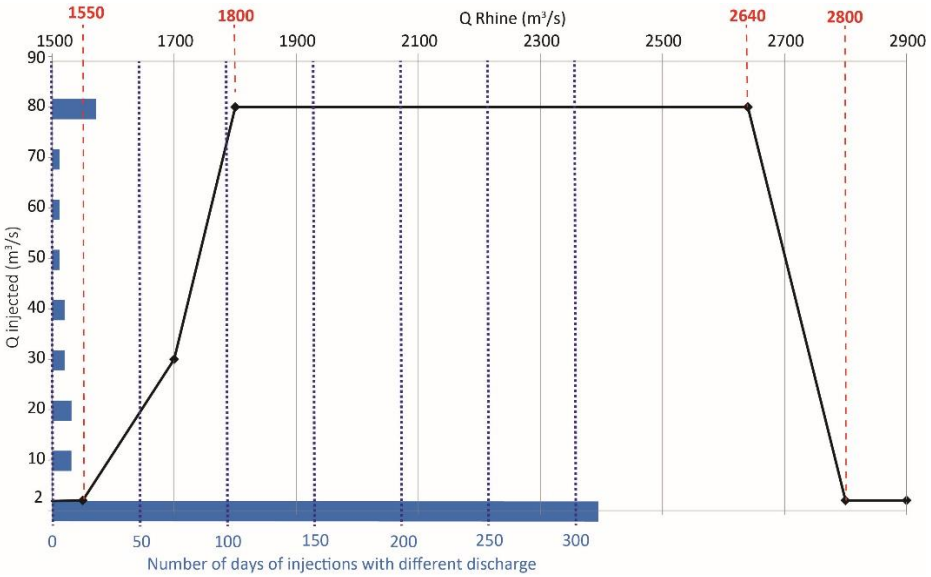
1. Pre- and post-restoration monitoring

Historical analysis was based on old maps, aerial photos and sedimentological investigations (grain size, thickness and deposition process). Interdisciplinary monitoring of pre- and post-restoration took into account (i) geomorphic evolutions including bedload transport (pit-tags, erosion chains, hydrophone) and morphological evolutions (lasergrammetry, photogrammetry, topographical and bathymetrical surveys), (ii) hydrological and hydrogeological variations (limnimetry, piezometry, gauging, TIR) and (iii) ecological changes (macrobenthos, riparian and aquatic vegetation, water-plant-sediment chemistry).

2 Infrared thermographic remote sensing survey

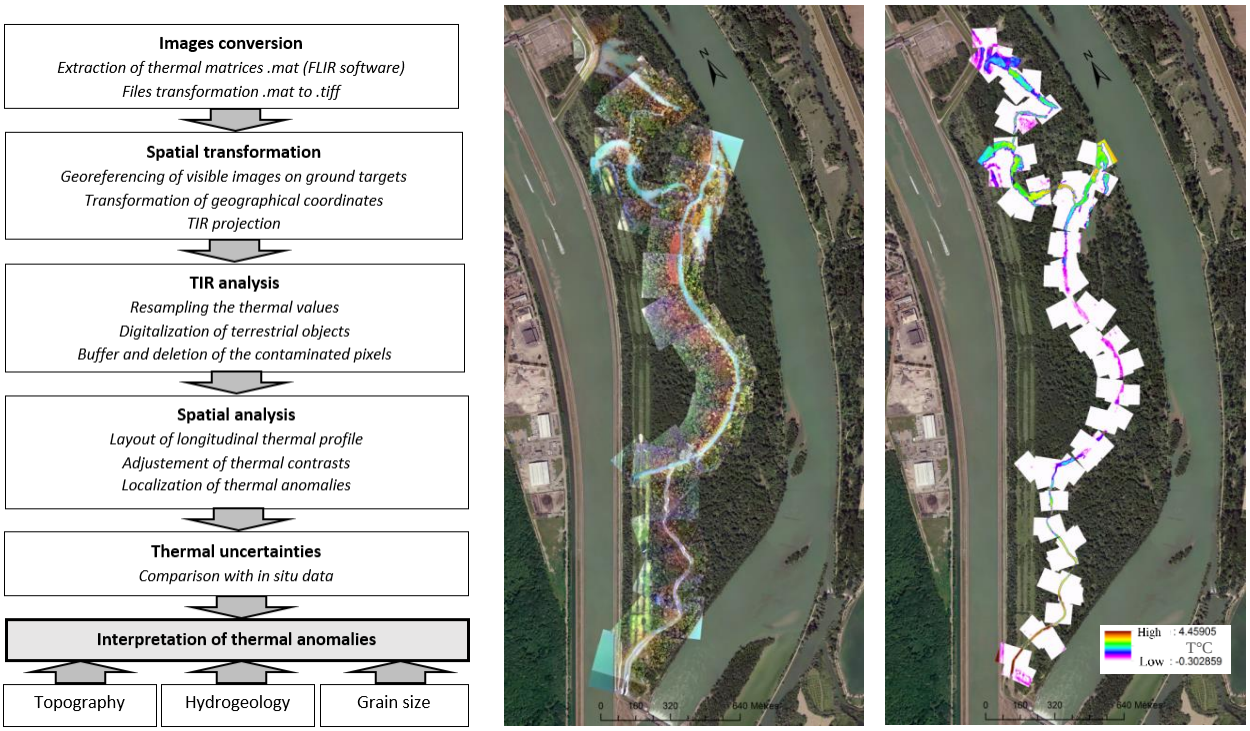
In January 2015, a thermographic survey was led to collect infrared and visible images along the water system by using two infrared cameras (B425 and E40). A processing chain was built (fig. 3) to

characterize and compare thermal patterns between the old channel and the new upstream connecting channel (Wawrzyniak and al., 2013).



Q Rhine	Q new channel	Days / year
Q<1550 or Q>2800	Q = 2	314
1565<Q<1650 or 2760<Q<2800	2<Q<20	11
1650<Q<1725 or 2725<Q<2760	20<Q<40	7
1725<Q<1755 or 2675<Q<2725	40<Q<60	4
1755<Q<1800 or 2650<Q<2675	60<Q<80	4
1800<Q<2650	Q=80	25

Fig.2 – Protocol of water inputs in the new channel in terms of discharge and mean duration, depending on the Rhine hydrological regime.



a. b. c.

Fig. 3 – a- TIR processing chain. b- Georeferencing visible images on the Orthophoto 2013. c- Transformation and georeferencing TIR images on the visible images.

Results

The cartographic overlaying (1828 – 2010) showed that the upstream of the Bauerngrundwasser corresponded to the main talweg of the Rhine. The palaeochannel is partly filled by sand and silt deposition. Therefore, the current watercourse was integrated into recent fine sediments which can be partly remobilized by dynamic floods (fig.1-c).

The hydraulic monitoring showed that the low level of energy, during both low and high water flows, was due to the agricultural dam backwater effect. The surface water-groundwater exchanges were also limited by channel clogging. Therefore, pre-restoration ecological surveys highlighted that the hydrosystem hosted typical lenitic water communities.

Diachronic 3D modelling, topographical and PIT-tags surveys (fig.4) indicated that morphodynamics was active in the new upstream channel in contrast with the former channel. On the new channel, TIR remote sensing allowed to identified areas of positive thermal anomalies (upwelling) on the downstream parts of the riffles, as it has been showed in others streams (Namour et al., 2015). Hydraulic, sedimentary, hydrogeological and geochemical models may allow median/long term estimation of flood effects on unclogging, bedload transport, surface water-groundwater exchanges and risk of remobilization of historical pollutants in the hydrosystem. Coarse grain size, active morphodynamics and diversity of thermal patterns should support the re-establishment of High specific fluvial communities.

In association with pre-restoration state and temporal trajectory, the post-restoration monitoring should guide future management decisions taking into account efficiency and sustainability.

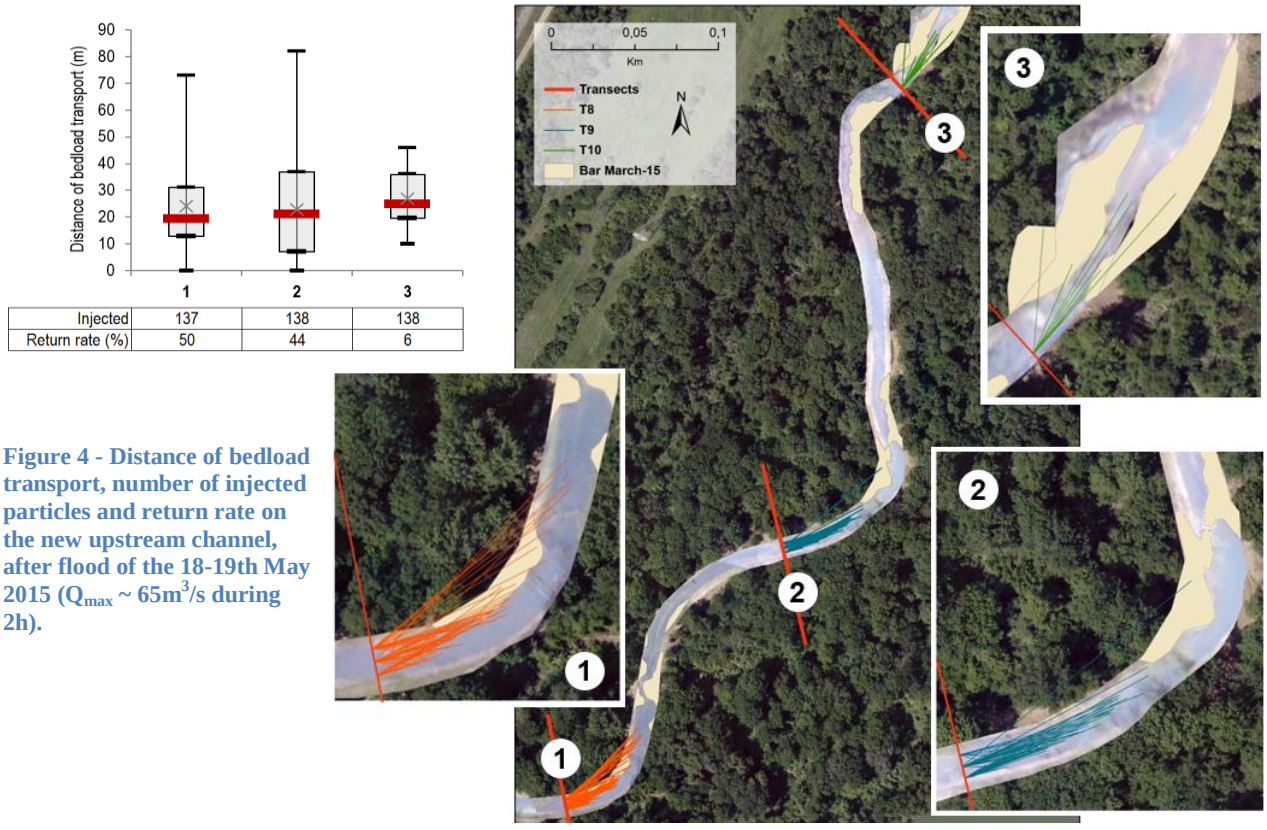


Figure 4 - Distance of bedload transport, number of injected particles and return rate on the new upstream channel, after flood of the 18-19th May 2015 (Q_{max} ~ 65m^3/s during 2h).

Acknowledgements

This study is funded by: Communauté Européenne (LIFE08 NAT/F/00471), CNRS, ZAEU (Zone Atelier Environnement Urbain), Agence de l'eau Rhin-Meuse, DREAL Alsace, Région Alsace, Département du Bas-Rhin, Électricité De France, ville de Strasbourg. We acknowledge Rodolphe Montagnon which realized the flight by powered paraglider for the TIR acquisition.

References

Namour, P., Schmitt, L., Eschbach, D., Moulin, B., Fantino, G., Bordes, C., Breil, P., (2015). *Stream pollution concentration in riffles geomorphic units (Yzeron basin, France)*, Science of the Total Environment. pp. 80-90.

Schmitt, L., Lebeau, M., Trémolières, M., Defraeye, S., Coli, C., Denny, E., Dillinger, M., Beck, T., Dor, J.-C., Gombert, P., Gueidan, A., Manné, S., Party, J.-P., Perrotey, P., Piquette, M., Roeck, U., Schnitzler, A., Sonnet, O., Vacher, J.-P., Vauclin, V., Weiss, M., Zacher, J.-N., Wilms, P. (2009). *Le "polder" d'Erstein: objectifs, aménagements et retour d'expérience sur cinq ans de fonctionnement et de suivi scientifique environnemental (Rhin, France)*. Ingénieries n°spécial, pp. 66-84.

Schneider, P., Vogt, T., Schirmer, M., Doetsch, J., Linde, N., Pasquale, N., Perona, P., Cirpka, O.A. (2011). *Towards improved instrumentation for assessing river-groundwater interactions in a restored river corridor*. Hydrology and Earth System Sciences 15, pp. 2531–2549.

Wawrzyniak, V., Piégay, H., Allemand, P., Vaudor, L., Grandjean, P. (2013). *Prediction of Water Temperature Heterogeneity of Braided Rivers Using Very High Resolution Thermal Infrared (TIR) Images*. International Journal of Remote Sensing 34, no. 13, pp. 4812–31.

MEASURING OF THE BACTERIAL GASEOUS EMISSION IN RIVER SEDIMENT

Jonathan Gervaix[1], Franck Poly[1], Pascal Breil[2], Philippe Namour[3,4]

1 Université de Lyon, Laboratoire d'écologie Microbienne, UMR 5557, Groupes fonctionnels microbiens & cycle de l'azote, 69100 Villeurbanne cedex
2 Irstea, UR HHLY & 3 Irstea, UR MALY, 5 rue de la Doua, F-69100, Villeurbanne, France
4 Université de Lyon, Institut des Sciences Analytiques, UME 5280, 5 rue de la Doua, Villeurbanne, FranceKeywords (5 at the most)

(topic IV, poster)

Context & Objectives

The microbial reactions of denitrification and methanogenes is which take place in the hyporheic zone produce CH4, N2O and N2 gases.

To better assess these emissions, a dedicated sampler operating at balanced pressure (no pressure effect) has been designed and tested on a small periurban river, belonging to the OTHU* project, in the aim to :

- Determine the nature of the gases in the rive
- Measure their rate of production
- Observe their spatial and temporal distributions

Material & Methods

The sampling device is composed of (Fig.1) :

a) a benthic bell that captures the gases emitted from the river sediment;
b) a balanced pressure collection cartridge allowing the storage of gases;
c) an ultrasonic immersion probe for quantifying the accumulated gaseous volume with time through a connected logger device.

After some days, gases are collected at the top of the cartridge by means of Venojects® which operates on the principle of a vacuum in the collecting tube, then analyzed by gas phase chromatography at the laboratory. Contamination by air along the operating chain has been tested.

Results

Gas volume collection with time (Fig.3). The average emission rate is of around 1 liter per m^2 a day. Gas release seems to occur when the global pressure (water + barometric) decreases and stop when it increases.

The composition of the collected gases is N_2, O_2, CH_4& CO_2. Variable proportions have been observed depending on the period (Fig.4).

The O_2 / N_2 ratio being different from that of the atmosphere it confirms the N_2 production by microbial communities of the river sediment. It has also been observed large quantities of CH_4 produced by methanogenic communities living in the river sediment.

Conclusions & perspectives

a) The device allows to collect hyporheic gases without atmospheric contamination;
b) Some gases are known for their greenhouse effect (CH4 & N2O). The presence of other undesirable gases like H_2S is to be sought;
c) The device allows the monitoring of indicators of the biodégradation activity of a river bed;
d) A next step is to include a portable chromatograph (or infra red analyzer) allowing to identify the nature of emitted gases during the collection;
e) A final step is to integrate all the system in a single unit in the aim to easily move it from a place to another and automatically collect data from a wireless network. This is a challenge for SME's which develop devices for the environmental monitoring.

INSTITUT DES SCIENCES ANALYTIQUES

écologie microbienne Lyon

EcoHydrology' 2015

Measuring of the bacterial gaseous emission in river sediment

Jonathan Gervaix[1], Franck Poly[1], Pascal Breil[2], Philippe Namour[3,4]

[1] Université de Lyon, Laboratoire d'écologie Microbienne, UMR 5557, Groupes fonctionnels microbiens & cycle de l'azote, 69100 Villeurbanne cedex
[2] Irstea, UR HHLY & [3] Irstea, UR MALY, 5 rue de la Doua, F-69100, Villeurbanne, France
[4] Université de Lyon, Institut des Sciences Analytiques, UME 5280, 5 rue de la Doua, Villeurbanne, France

irstea

Context & Objectives

The microbial reactions of denitrification and methanogenes is which take place in the hyporheic zone produce CH4, N2O and N2 gases.
To better assess these emissions, a dedicated sampler operating at balanced pressure (no pressure effect) has been designed and tested on a small periurban river, belonging to the OTHU* project, in the aim to :

- Determine the nature of the gases in the river
- Measure their rate of production
- Observe their spatial and temporal distributions

EcoHydrology 2015 Lyon, France, from 21 to 23 September

Material & Methods

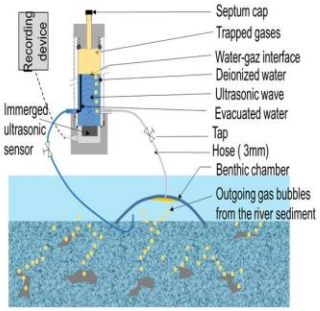


Figure 1 : Sampling system details

The sampling device is composed of (Fig.1) :

a) a benthic bell that captures the gases emitted from the river sediment;
b) a balanced pressure collection cartridge allowing the storage of gases;
c) an ultrasonic immersion probe for quantifying the accumulated gaseous volume with time through a connected logger device.

After some days, gases are collected at the top of the cartridge by means of Venojects® which operates on the principle of a vacuum in the collecting tube, then analyzed by gas phase chromatography at the laboratory. Contamination by air along the operating chain has been tested.

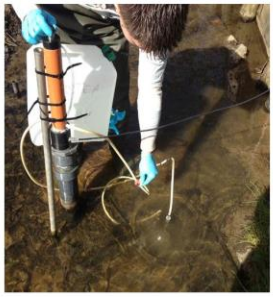


Figure 2 : System in operation on the field,

Results

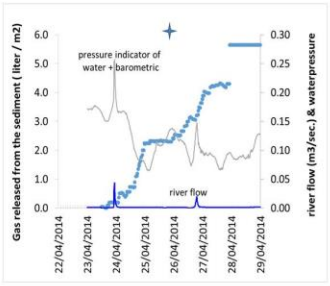


Figure 3 : dynamic of the gaz production per m² Influence of the barometric pressure.

Gas volume collection with time (Fig.3). The average emission rate is of around 1 liter per m^2 a day. Gas release seems to occur when the global pressure (water + barometric) decreases and stop when it increases.

The compositions of the collected gases is N_2, O_2, CH_4 & CO_2. Variable proportions have been observed depending on the period (Fig.4).

The O_2 / N_2 ratio being different from that of the atmosphere it confirms the N_2 production by microbial communities of the river sediment. It has also been observed large quantities of CH_4 produced by methanogenic communities living in the river sediment.

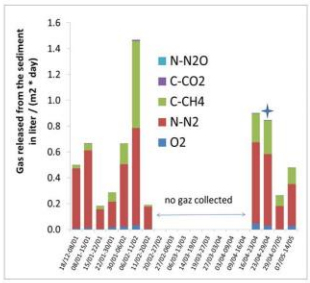


Figure 4: Varying volumes of the collected gases for weekly sampling over two periods.

Conclusions & perspectives

a) The device allows to collect hyporheic gases without atmospheric contamination;
b) Some gases are known for their greenhouse effect (CH4 & N2O). The presence of other undesirable gases like H_2S is to be sought;
c) The device allows the monitoring of indicators of the biodégradation activity of a river bed;
d) A next step is to include a portable chromatograph (or infra red analyzer) allowing to identify the nature of emitted gases during the collection;
e) A final step is to integrate all the system in a single unit in the aim to easily move it from a place to another and automatically collect data from a wireless network. This is a challenge for SME's which develop devices for the environmental monitoring.

Acknowledgement : we thank the National Reasearch Agency for having supported the ANR-10–ECOT-00–02 project which provided funds to develop this demonstration device, and also the OTHU project (Field Observatory for urban Water Management - http://www.graie.org/othu/) for its data.

ANR

EPEC Épuration en eau courante

INFLUENCE OF EXTERNAL RESISTOR ON DENITRIFYING ACTIVITY OF A PURE STRAIN OF PSEUDOMONAS STUTZERI IN MICROBIAL FUEL CELLS

L. Jobin, *Institut des Sciences Analytiques UMR CNRS 5280 (ISA), Université Claude Bernard Lyon 1, 5 rue de la Doua, 69100 Villeurbanne, France, lucas.jobin@isa-lyon.fr*.

T. Pommier, *Laboratoire d'Ecologie Microbienne UMR CNRS 5557 (LEM), Université Claude Bernard Lyon 1, 43 boulevard du 11 Novembre 1918, 69622 Villeurbanne, France, thomas.pommier@univ-lyon1.fr*.

C. Jose, *Institut des Sciences Analytiques UMR CNRS 5280 (ISA), Université Claude Bernard Lyon 1, 5 rue de la Doua, 69100 Villeurbanne, France, Catherine.JOSE@isa-lyon.fr*.

J. Gervaix, *Laboratoire d'Ecologie Microbienne UMR CNRS 5557 (LEM), Université Claude Bernard Lyon 1, 43 boulevard du 11 Novembre 1918, 69622 Villeurbanne, France, gervaixjonathan@yahoo.fr*.

Ph. Namour, *Institut des Sciences Analytiques UMR CNRS 5280 (ISA), Université Claude Bernard Lyon 1, 5 rue de la Doua, 69100 Villeurbanne, France, philippe.namour@univ-lyon1.fr*.

Key words: microbial fuel cell, anode redox potential, bacterial metabolic activity, greenhouse gas, self-purification ecosystem service (Topic 4.5 and 1.3 are concerned)

Topic of this work: This work is at the interface between microbiology and electro-chemistry. Microbial fuel cell (MFC) are bio-electrochemical system which implement bacteria to produce electricity. We propose to use it for water bioremediation purpose.

Operational application: This study is part of a Ph. D project aiming at designing a sedimentary microbial fuel cell (SMFC) to promote self-purification process (biodegradation of organic matter) and reduce greenhouse gas emissions in river and sewers. Processes involved are highly dependent on the sedimentary redox potential. This preliminary Ph. D work aims to better understand the relation between the anode redox potential, driven by the external resistor, and the denitrifying activity of a pure microbial strain (*Pseudomonas stutzeri*) in a lab MFC model.

Originality of this work: This first work implements a microbial strain that has never been used in this kind of bio-electrotechnology. *Geobacter sulfurreducens* and Shewanella *Oneidensis* are the most commonly used. Among the denitrifying Pseudomonas, only some of them have been studied in MFCs such as *Pseudomonas aeruginosa*, *P. denitrificans* or *P. alcaliphila*. Few MFC studies focus on how the external resistor (R ext) influences the anode redox potential (ORP) and consecutively the bacterial behavior. Most of the time, implemented systems are complex bacterial consortia whose evolution during MFC culture is hard to apprehend. Moreover, the anode ORP isn't exploited so much in MFC studies. Finally, the link between evolution of bacterial communities and the anode ORP in MFC isn't always clear.

Here, we propose to work on a pure strain for an easier tracking over time of the biological system. As a result, it should be possible to clearly understand the external resistor impact on the current generated by the microbial strain, and the way the anode ORP is affected according to the ox/red

balance. Another important aspect to study is the relation between the anode ORP and the metabolism of *P. stutzeri*. How the denitrifying gas production N_2O/ N_2 evolves depending the anode ORP? The answer of this question represents an important operational interest. Indeed, we plan to use the first results to develop an ORP control strategy based on R ext to influence the microbial activity. The next goal will be to reduce the gas production (CH_4 and H_2S in particular) in more complex microbial systems such as sediments using the ORP strategy previously developed.

Method: *P. stutzeri* will be cultivated in classic "H-shaped" MFCs (two chambers separated by a CMI Ultrex membrane). The culture medium used in the anode compartment is a phosphate-buffered TSB medium. The cathode compartment is filled with phosphate-buffered-deionized water. Anode and Cathode are made of carbon felt, for a respective surface of 21 cm² and 27.7 cm². Three sets of triplicate are used: 3 controls and 6 tests. Reactors are operated at 30°C. Preliminary work is to develop biofilms in each MFCs at fixed external resistors by replacing regularly the culture medium. Current production during biofilms growth is the reference quantity. The latter is monitored thanks to a data acquisition system which enable as well the acquisition of all others relevant electric quantities such as cathode/anode ORP, cell voltage, power output... Then, external resistors are changed and KNO_3 is introduced in the anode chamber of some MFCs so that the strain can start its denitrifying activity. Gas production is monitored by a micro-GC.

PESTICIDES DYNAMICS IN THE CATCHMENTS AND POSSIBILITIES OF REDUCTION THEIR TRANSFER TO FRESHWATER ECOSYSTEMS AND COASTAL ZONES

P. Jarosiewicz[1,2], M. Kwiatkowska[2], B. Bukowska[2], M. Zalewski[1]
1. European Regional Centre of Ecohydrology, Polish Academy of Science, Lodz, Poland.
2. Department of Environmental Pollution Biophysics, University of Lodz, Lodz, Poland.
pawel_jarosiewicz@wp.pl

Pesticides, Ecosystem Biotechnology, Glyphosate, Toxicity
Topic 4: Environmental monitoring and measuring of water-related natural processes

In the face of continued growth of the human population, food production becomes a major problem. By now, the most popular tool enabling increase of crop productivity are pesticides. Major problem stemming from the applying chemicals to the environment is their uncontrolled drift into soil and water. Dynamics of pesticides in the catchment are connected with both abiotic (sorption, ion exchange) and biotic (metabolism, enzyme degradation) factors.

Due to regulation of European Parliament 1107/2009 it is important to assess cytotoxicity and genotoxicity, not only for the parent substance but also its metabolites. Moreover verifying, which of these compounds are more toxic is required. Understanding of the molecular pathways of action is extremely important in the context of the environmental risk assessment. Water Framework Directive (WFD) 2000/60/EC of the European Parliament assume achievement good chemical status of water in European Union. Thus, to achieve this aim there is a strong need of low-cost, large-scale solutions.

Glyphosate (*N*-(phosphonomethyl)glycine) is an active ingredient of the most widely used pesticide formulations to protect agricultural and horticultural crops. Exposure to glyphosate is common. It is detected in water (0.7 mg/dm^3), soil (up to 5 mg/kg), beans (20 mg/kg) and in the blood of general population (73.6 ± 28.2 ng/ml). Annually, approximately 900 million kg of glyphosate is entering the environment. Because of nature of the phosphonate molecules and specific plant metabolism, it is common to found in the environment of two major metabolites of glyphosate,. aminomethylphosphonic acid (AMPA) and methylphosphonic acid (MPA).

Peripheral blood mononuclear cells were incubated with various concentrations of studied compounds. Changes in cell viability were observed even at the concentration of 250 µM MPA. The smallest adverse cytotoxic effect on the cells was found for parent substance. The results showed that mode of toxicity changes differ between MPA, glyphosate and AMPA. Evaluating genotoxicity using the comet assay showed a concentration-dependent increase in DNA damage for all studied compounds.

Toxicity of glyphosate and its metabolites was observed at concentrations higher than those found in the environment. Metabolites have a similar effect on PBMCS but may act through a completely different molecular mechanisms.

Ecohydrology creates systemic framework on how to use ecosystem processes as a tool for environmental and societal problems. Toxicological studies connected with constant monitoring should be the first step of systemic approach in reducing amount of hazardous substances in environment. This monitoring of threats is background for second step which is assessment of cause-effect relationship. Glyphosate mode of action is inhibiting of shikimate pathway which occurs in plants and Procaryota. Therefore, it can cause harmful effects not only to weeds but also to the richness of

organisms living in soil and water. Evidences of toxicity was founded for many aquatic organisms (i.e. *Daphnia magna, Siriea armata, Danio reiro*). Also there are evidences for endocrine disruptor character of some pesticides. Consequences could be tremendous, and lead to thropic chain disruptions. In March this year, World Health Organization classified glyphosate as "probably cancerogenic for humans". Therefore, reduction of pesticides transfer in environment is direct challenge in human health protection.

Next steps are development of ecohydrological methods and system solutions. There are evidences of effectiveness in reducing pesticides for riparian buffer zones and wetlands. Great possibilities come with ecosystem biotechnologies, such as constructed wetlands and denitrification walls. Achieving of the WFD goals will be possible by reduction of pollutant emission and enhancement of absorbing capacity and self purification of landscape and freshwater ecosystem.

Pesticides dynamics in the catchments and possibilities of reduction their transfer to freshwater ecosystems and coastal zones

P. Jarosiewicz[1,2], M. Kwiatkowska[2], B. Bukowska[2], M. Zalewski[1]

1. European Regional Centre of Ecohydrology, Polish Academy of Science, Lodz, Poland.

2. Department of Environmental Pollution Biophysics, University of Lodz, Lodz, Poland.

p.jarosiewicz@erce.unesco.lodz.pl

Pesticides, Ecosystem Biotechnology, Glyphosate, Toxicity

In the face of continued growth of the human population, food production becomes a major problem. By now, the most popular tool enabling increase of crop productivity are pesticides. Major problem stemming from the applying chemicals to the environment is their uncontrolled drift into soil and water.

Plant Protection Products (PPP) market is very flexible and differ in other countries. In Poland (fig. 1) trends are similar to world market. Most popular group of pesticides are herbicides. The most common agent in this group is glyphosate (G).

Annually, approximately 900 million kg of G is entering the environment. Because of nature of the phosphonate molecules and specific plant metabolism, it is common to found in the environment of two major metabolites of glyphosate, aminomethylphosphonic acid (AMPA) and methylphosphonic acid (MPA).

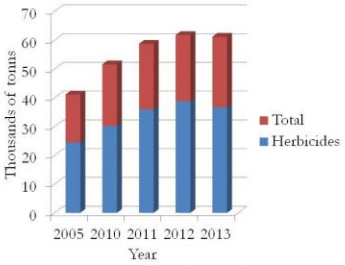


Fig.1 Market of pesticides in Poland with allowance of herbicides. Data from Statistical Yearbook of Agriculture, 2014, Poland.

1 Evaluation of toxicity is essential for good communication between researchers and policy makers. It is also important to increase users consciousness and understand cause-effect relationship in ecosystem. Glyphosate shows genotoxicity effects (fig. 3) at lower concentrations than cytotoxicity (fig. 2). By understanding toxicity pathways we can create predictions of potential ecosystem effects of each substance.

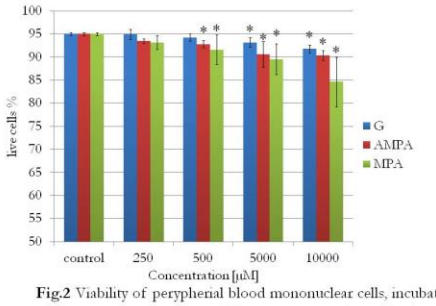


Fig.2 Viability of perypheral blood mononuclear cells, incubated with G, AMPA and MPA in different concentrations. (*) Changes statistically significant at $p < 0.05$.

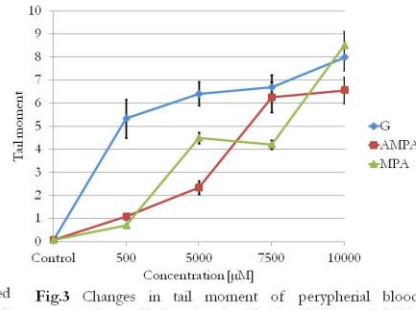


Fig.3 Changes in tail moment of perypheral blood mononuclear cells incubated with G, AMPA and MPA. Results from alkaine comet assay.

2 Environmental fate of PPP is strongly connected with their chemical composition. Adsorbed phase moves faster with surface runoff, however water soluble PPP could be more frequently find in subsurface runoff.

Dynamics of pesticides in the catchment are connected with both **abiotic** (sorption, ion exchange) and **biotic** (metabolism, enzyme degradation) factors.

3 Creation of Solution Systems is impossible without the knowledge from the former steps. There are evidences of effectiveness in reducing pesticides for riparian buffer zones and wetlands. Great possibilities come with **ecosystem biotechnologies**, such as constructed wetlands, biogeochemical barriers and denitrification walls. Achieving of the Water Framework Directive goals will be possible by reduction of pollutant emission and enhancement of absorbing capacity and self purification of landscape and freshwater ecosystem.

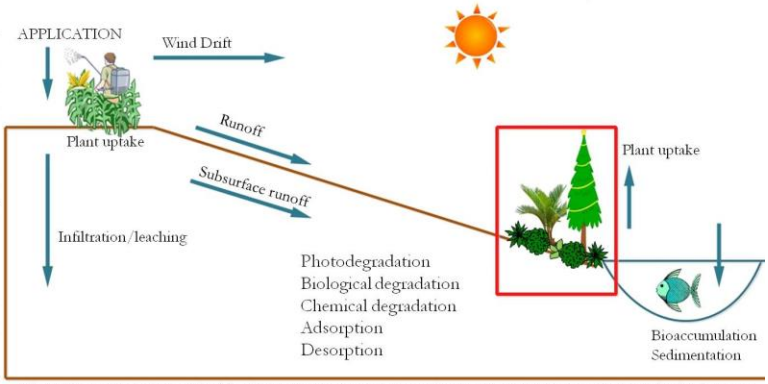


Fig. 4 The optimization of highly efficient ecotone zones for reduction of pesticides transfer from the landscape to the freshwater ecosystem and bioaccumulation.

STATISTICAL GENERATION OF TRAINING SETS FOR MEASURING NO3- AND NH4+ I NATURAL WATERS BY A NOVEL MULTI-ANALYTE ION SELECTIVE ELECTRODE ARRAY

Amy V. Mueller	Massachusetts Institute of Technology	amym@mit.edu
Harold F. Hemond	Massachusetts Institute of Technology	hfhemond@mit.edu

Key words

In-situ instrumentation; adaptive sampling; real-time measurements; ion selective electrodes; sensor arrays

[4.5 Real Time monitoring & smart monitoring]

Topic of this work

Inorganic nitrogen, in the form of nitrate and ammonium ions, is a key nutrient as well as a major ingredient in commercial fertilizers and participant in redox, acid-base, and photochemical processes of natural waters, leading to spatiotemporal patterns of ion concentrations at scales as small as meters and hours. Nitrogen leeching from soils and/or runoff from soil surfaces may be responsible for situations as diverse as supporting growth in nutrient-limited environments and driving eutrophication in surface and coastal waters. Because of the many natural N transformation pathways, movement of nitrogen from forests and agricultural fields through surface and ground waters to coastal systems is difficult to track, however an improved understanding of these connections is critical for implementation of effective regulations to balance demands of human populations (high-density food growth, waste water treatment, etc.) with protection of downstream ecosystems.

Current options for measurement of nitrogen species include (1) labor- and cost-intensive grab sampling and (2) in-situ monitoring via expensive instrumentation, generally adapted from proven laboratory methods (e.g., colorimetric, UV absorption techniques). This work focuses on an alternative architecture for in-situ measurement of nitrogen species using inexpensive ion-selective electrode (ISE) sensors, a strategy that requires careful consideration of effects of interferences from other potential constituents across a wide range of environment types but would enable deployment of a much larger number of instruments without increased funding requirements.

Research question (or operational application)

The goal of this research was development of an affordable instrument for in-situ measurement of inorganic nitrogen species (along with the full charge balance of natural waters) with sample measurement times of <5 minutes, requiring:

(1) identification of existing field-adaptable sensor hardware, for which cost was a more important metric than analyte specificity
(2) a process for lab-based design and calibration of a multiprobe sensor to be used across widely varying environmental conditions, given the high costs and logistical difficulties associated with collection of 'training' samples from a representative set of field sites
(3) training and calibration of instrument software; validation of instrument functionality

Originality of this work

This work is aimed at improving the resolution of data available for understanding the cycling of nutrients and other ionic analytes in the environment, enabling real-time adaptive sampling as well as

long-term monitoring at high temporal resolution[1]. Understanding of environmental systems in this manner is critical for identification and understanding of non-point source nutrient pollution sources and recommendation of effective remediation or regulation strategies.

The unique software and signal processing methodologies utilized in this research are inspired by algorithms developed in other fields (e.g., artificial intelligence and machine learning) but coupled with an understanding of the chemical constraints governing fresh water systems. The overall strategy of this research is to take advantage of existing knowledge to develop a comprehensive understanding of the problem to be addressed, build upon demonstrated hardware and software successes by identifying and overcoming key shortcomings relative to their use in the target application, and avoid integrating assumptions about environmental characteristics into the instrument measurement strategy[2].

Methods and Results

This work presents a rationalized process for development of in-situ instrumentation for NO3- and NH4+ including (1) a novel methodology for overcoming signal interferences and (2) a statistical-modeling strategy for instrument design, training/calibration, and validation. The statistical model reveals that concentrations of major ionic constituents (1) strongly co-vary and (2) are multi-modal across the New England region of the United States (the 5-state target region for experimental analysis). In addition to informing design of a statistically appropriate training set and highlighting the necessity of characterizing these known interferents for nitrate and ammonium ISEs, it is suggested that the strong covariance of constituents across environmental samples can be exploited through appropriate signal process mechanisms to further improve estimates of minor constituents such as NO3- and NH4+ (and potentially poorly characterized constituents such as sulfate or phosphate). The resulting prototype for a field-deployable system for quantification of inorganic nitrogen species was comprised of eleven commercially-available ion selective electrodes (ISEs) and sensors for temperature and conductivity combined with a novel application-optimized artificial neural network (ANN) signal processing technique. Testing against the highly varied chemical background found in New England surface waters demonstrated accurate, unbiased quantification of nitrate and ammonium *at natural environmental levels* (+/- 20% down to <10uM) in *unprocessed* water samples.

Acknowledgements

Funding for this work was provided by the National Science Foundation (graduate research fellowship), the Geological Society of America (graduate research grant), and MIT Sea Grant.

[1] Note that long-term deployment of any ISE instrumentation in the environment will necessarily require collection of occasional calibration/validation samples (to demonstrate a lack of or correct for drift); current work by the corresponding author is developing a novel in-situ sampler for automated collection of water samples with online preservation, which could be easily co-deployed with ISE instruments to obviate the need for field visits simply to collect calibration/validation samples.

[2] Recently released commercial instrumentation using ISEs for measurement of single analytes (nitrate, ammonium, or chloride) relies upon an interference correction for other ions in surface waters that assumes “average” distribution of ions in surface waters; it is significant to note that, according to manufacture literature, outlier measurements explicitly require collection of grab samples for lab analysis to differentiate between high levels of the target analyte and high levels of interfering ions.

SYSTEMATIC METHODOLOGY OF ANALYSIS FOR REVEALING THE POLLUTANT DISTRIBUTION IN RIVER

Philippe NAMOUR[1,2], Laurent SCHMITT[3], Pascal BREIL[4]

[1]University of Lyon, Institute of Analytical Sciences, UMR 5280, 5 rue de la Doua, F-69100, Villeurbanne, France, philippe.namour@univ-lyon1.fr

[2]Irstea, UR MALY, 5 rue de la Doua, F-69100, Villeurbanne, France, philippe.namour@irstea.fr
[3]University of Strasbourg, Laboratoire Image Ville Environnement UMR 7362, 3 rue de l'Argonne, F-67083, Strasbourg, France, laurent.schmitt@unistra.fr

[4]Irstea, UR HHLY, 5 rue de la Doua, F-69100, Villeurbanne, France, pascal.breil@irstea.fr.

Key words:pollution, hotspot, riffle geomorphic unit, hyporheic zone, urban stream

(topicIV)

Topic of this work

We deploy a methodology in order to locate the accumulation zones of heavy metals (Cr &Pb) and organic matter (N & C) in the longitudinal dimension of pool-run-riffle sequences in a stream. To this end, both benthic and hyporheic sediments were investigated. Our working hypothesis was that geomorphic units could direct the flow in the hyporheic zone in different ways, and thereby determine the chemical element distribution in the stream sediment.

Research question (or operational application)

An understanding of mechanisms involved in pollutant hotspot development in streams would improve our understanding of the processes controlling water quality, and could help the development of innovative management strategies to improve the capacity of nutrient assimilation and/or pollutant removal. Pollution hotspots can be important from biogeochemical and ecotoxicological points of view because they can create the conditions for an efficient chemical and (micro)biological activity. In this way, clean-up efforts can be modulated according to the contamination intensity of hotspots, and in the case of the rehabilitation of an urban stream frequently subject to CSO discharges, some artificial trapping zones could even be designed to concentrate pollutants in a limited area which could later be treated more easily.

Originality of this work

Our results prompt several issues of high relevance for water quality monitoring and management, and for stream restoration/rehabilitation. As hyporheic sediments concentrate more pollutants than benthic ones, in particular in riffle geomorphic units, these compartments should be considered as priority investigation zones in chemical quality assessments of waterways.The riffle hyporheic compartment must at least not be forgotten in monitoring and sampling strategies and methodologies. The latter should use mapping of longitudinal and vertical distributions of biogeochemical hotspots in streams, on the basis of riffle geomorphic units.

Data and / or method
Two reaches were monitored on the Chaudanneperi-urban stream, upstream and downstream a CSO outlet. The stream channel was characterized into different in-stream geomorphic units (riffles, pools and runs) according to previously defined characterizations.The stream reaches were systematically crossed by transects spaced 2 m apart, and benthic and hyporheic samples were collected from downstream to upstream at the center of each transect. A total of 18 sediment samples (both benthic and hyporheic) were collected downstream from the CSO on 9 March 2009 and upstream from the CSO on 16 November 2009.

Two heavy metals (chromium and lead) were selected as model pollutants to explore the dynamics of pollutants in the stream bed.The hydraulic conductivities K were measured using the injection-relaxation test method and Hyporheic flow in the different geomorphic units was calculated using Darcy's law.

Main results
Our main result is to clearly demonstrate that:

- Pollution contents is clearly highest in the hyporheic zone, which is globally a pollution storage zone,

- Hyporheic pollutant concentration is not equally distributed along stream reaches, but is strongly linked to in-channel geomorphic units, in particular riffles.

- Pollutant distribution in the hyporheic zone of streams is not a stochastic phenomenon. Hydraulic and geomorphic factors (the second controls the first during low and mean flow conditions) explain their spatial distribution.

Data and / or method
Discuss what they bring in terms of new knowledge and/or in terms of operational application and what are the perspectives that they open for the topic of interest.

By stratifying the studied stream into distinct geomorphic units and by sampling each unit separately (particular attention should be given to riffles), in both the surface and hyporheic compartments, the complex 2-dimensional structure of contamination can be better understood, and local hotspots delimited. In this light, new sampling methodologies that take into account this 2-D structure of pollution will be particularly useful for monitoring the actual chemical status of streams. This is at variance with the commonly accepted approach to stream pollution assessment that recommends preferential sampling of fine sediments accumulated in dispositional zones, i.e. in-stream habitats where energy corresponding to the falling limb of the flow hydrograph and low flows is weak, as in the benthic compartment of pools and runs.

Aknowledgements
The authors thank the French National Research Agency (INVASION ANR-08-CESA-022 and EPEC ANR-10-ECOT-007), the Field Observatory in Urban Water Management (OTHU - www.othu.org/ - FED 4161), the Greater Lyon, the Rhône-Mediterranean & Corsica Water Agency, and the Rhône-Alpes Region for their scientific and financial support.

WHAT WE LEARNED FROM TURBIDITY BASED MEASUREMENT FOR THE MONITORING OF SUSPENDED SEDIMENT AND POLLUTANT BOUND-SEDIMENT IN RIVERS?

Némery Julien,Université Grenoble Alpes, LTHE F-38000 Grenoble, FranceJulien.nemery@grenoble-inp.fr

Aubert Coralie, Université Grenoble Alpes, LTHE F-38000 Grenoble, France
Belleudy Philippe, Université Grenoble Alpes, LTHE F-38000 Grenoble, France
Dutordoir Solène, Université Grenoble Alpes, LTHE F-38000 Grenoble, France
Duvert Clément, EEBS, Queensland University of Technology, Brisbane, Australia
Esteves Michel, IRD, LTHE F-38000 Grenoble, France

Gratiot Nicolas, IRD, LTHE F-38000 Grenoble, France

Legout Cédric, Université Grenoble Alpes, LTHE F-38000 Grenoble, France
Marçais JohannaUniversité Savoie Mont-Blanc, LCME, Chambéry, France
NavratilOldrich, Université Lyon 2, Lyon, France

Nord Guillaume, Université Grenoble Alpes, LTHE F-38000 Grenoble, France
Piot Christine, Université Savoie Mont-Blanc, LCME, Chambéry, France Strady Emilie,IRD, LTHE F-38000 Grenoble, France

Key words (turbidity, nutrients, pollutants, flux, river)

(Topic 4: Environmental monitoring and measuring of water-related natural processes: Sub-topic 4.1 Physical-chemical & biological sensors)

Topic of this work

Suspended sediment (SS) is a key parameter in water quality management policy. Increasing attention in environmental research has been directed to the transport and fate of SS in watersheds, because of its role as a vehicle for pollutant bound-sediment such as heavy metals, organic micro-pollutants, and nutrients such as phosphorus (P), nitrogen (N) or carbon (C). The quantification of particulate fluxes in rivers is then a key issue for watershed management.

Research question (or operational application)

River SS and pollutant concentrations present high temporal and spatial variations. Adoption of an adequate sampling frequency is thus essential for obtaining reliable SS and associated-pollutant load estimates. Turbidity is now widely used to monitor SS concentrations in rivers and some recent studies show the potential for the monitoring of pollutant bound-sediment. The question is: is there any relationship between particulate compounds and SS concentrations that allow using high frequency turbidity database to improve particulate compounds monitoring and flux calculation?

Originality of this work

The advantage of using the turbidity in rivers is the acquisition of a high frequency database (hourly or sub-hourly) which limits the uncertainties in the calculations of flux. The originality of the approach is to explore and exploit the relationships SS/pollutant (if any) coupled to the turbidity high frequency data to obtain a high frequency particulate pollutant database. Two major points have to be considered in this approach: i) the quality of the relationship SS/turbidity and ii) the quality of the relationship SS/particulate pollutant. These relationships are very dependent on the hydrology of the river and the season. To build these relationships at best it is essential to measure and analyze changes in SS and particulate pollutants in a wide range of hydrological events (ideally over an hydrological season).

Data and / or method

Turbidity sensors have been used in several studies conducted over several watersheds in France (Alps and Ardèche) and in Mexico (Cointzio watershed). Classically an automatic sampler has been coupled and is controlled by the turbidity sensor. It allowed pumping water routinely every day and at 1-hour time steps, for instance, during the high suspended sediment events (flood, hydraulic flush, debris flows). Databases of SS/turbidity were acquired over several years and supplemented by specific measurements of particulate substances on SS (particulate P, particulate N, Particulate Organic Carbone –POC–, trace metals and PAHs).

Main results and discussion

Figure 1 presents an example of the relationships found in the Isère River (French Alps). In this case the two relationships are of good quality and allow obtaining high frequency databases (hourly) of SS (via the relationship SS/turbidity) and POC (via the relationship POC/SS). Uncertainty about each relationship is then understood from the dispersion around the regression line.

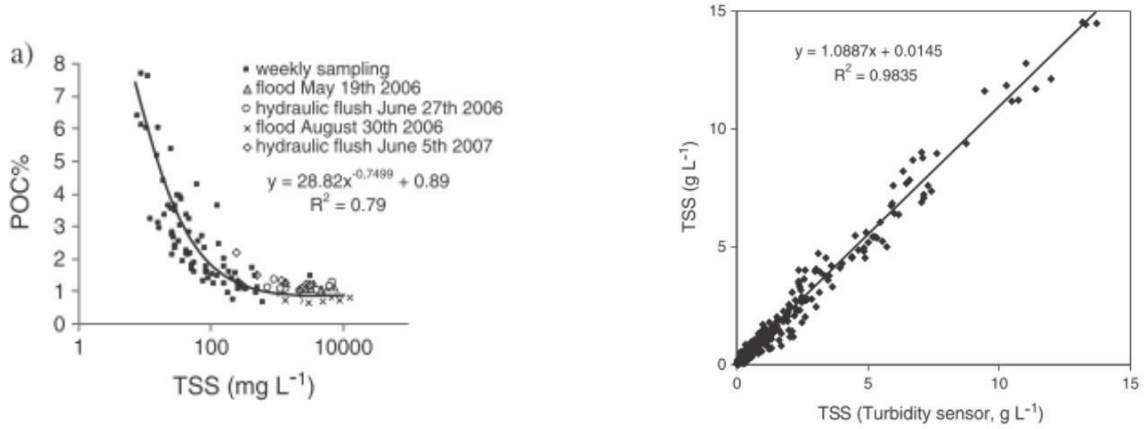


Figure 1 :a) Relationship between SS and Particulate Organic Carbon b) Relationship between SS and turbidity measurement in the Isère River (French Alps)

These high frequency database of SS and POC coupled with discharge data are used to estimate annual flux of SS and POC with an uncertainty <10-15 %. In this case such an approach is far more satisfying than the calculation flow based on discrete data at low frequencies (weekly, monthly) that is found in conventional monitoring of quality control services of rivers. Similar relationships between SS and particulate P and N, metals and PAHs were investigated on different case studies and will be presented in the communication. The analysis of these relationships opens the relevant perspectives on the use of the turbidity measurement for monitoring particulate pollutants in rivers.

OXYGEN PROFILE IN THE HYPORHEIC ZONE : WOODEN STAKE METHODOLOGY IMPROVEMENT

M.N. Pons, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

P. Namour, Institut des Sciences Analytiques, UMR CNRS 5280, 5 rue de la Doua, 69100 Villeurbanne, France
P. Breil, HHLY, IRSTEA, 5 rue de la Doua - CS70077 69626 Villeurbanne cedex, France

P. Marmonier, A. Vienney, LEHNA, Université Lyon 1, 43, Boulevard du 11 novembre 1918, 69622 Villeurbanne cedex, France

F. Guérold, P. Wagner, Laboratoire Interdisciplinaire des Environnements Continentaux (UMR 7360 CNRS), Université de Lorraine, Campus Bridoux, Rue du Général Delestraint, 57070 Metz cedex, France

G. Guibaud, GRESE, Université de Limoges, 123, avenue Albert Thomas, 87060 Limoges cedex, France

Key words (5 at the most)

Hyporheic zone, oxygen profile, scanning, wooden stake (4.1, 4.6)

Research question

River hyporheic zone is recognized as an important compartment of aquatic systems. Its study, especially in terms of vertical gradients, is not easy. The oxygen profile is a driver for chemical and biological processes taking place at different depths below the river floor. Marmonier et al. (2004) have proposed a simple way to investigate the vertical oxygen gradient by inserting wooden stakes into the hyporheic zone. They are recovered after a few weeks and the color taken by the wood is related to the oxygen regime (aerobic, anoxic/hypoxic, anaerobic). In the original description of the procedure, the stakes are read on site as the colors fade away after drying. The procedure has been modified by taking images of the stakes with a flat-bed scanner. It allows to store the information into a database and facilitates comparison between sites or, for a given site, with respect to time. However, when the sites are distant one from another, different scanners might be used and it is necessary to intercalibrate the scanners.

Data and / or method

All 30-cm long stakes have been cut from 6 mm x 13 mm x 250 cm pine battens from the same provider (Leroy-Merlin, France). Each stake is fitted at the top with a glass 10 mm x 2 mm RFID tag (Biolog-id, Bernay, France). The insertion of the stake into the river bed is facilitated by preparing the hole with a digging bar. Stakes have been used in rivers with different geologies and WFD status in the Lorraine, Limousin and Rhône-Alpes regions. To keep the stakes moist after retrieval, they are protected by plastic wrap, stored in a cold box, transported quickly to the lab and kept at 4°C in the

dark until scanned. Three flat-bed scanners (two Epson Perfection 4490 with different settings and a Epson Perfection V700) have been used. Each stake is imaged (300 dpi) together with two references stakes (a dry stake not exposed to water (R1) and a black-painted stake (R2)). The RGB images are stored in TIFF format. For calibration purpose, Munsell Soil Color patterns have been imaged in the same conditions as stakes. Images are analyzed using Visilog 6.9 (Noésis). The color gradient of each stake is evaluated by the color average along the width of the stake in N equidistant depths.

Main results

In order to be able to compare stakes scanned on different flat-bed scanners, linear transformation equations for the Red, Green and Blue channels are derived based on the Munsell Soil Color patterns.
= · + = · + = · +

Figure 1 shows the red-channel correlation for one of the slave scanners (V700). In Figure 2 the reference stakes scanned by the slave scanners are compared to the same stakes scanned by the master scanner after applying the previous equations. In Figure 3, the Munsell H10R Colors scanned on the master scanner and one of the slave scanner are compared. The methodology is ready to be applied on the wooden stakes for oxygenation gradient analysis.

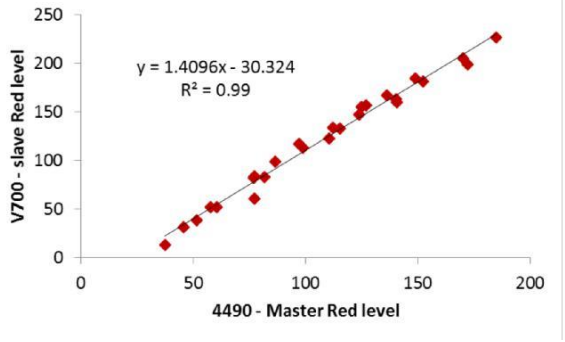


Figure 1 : Red-channel correlation

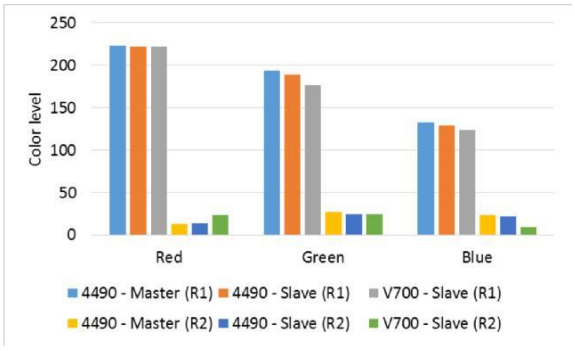


Figure 2 : Comparison of the refernce stakes

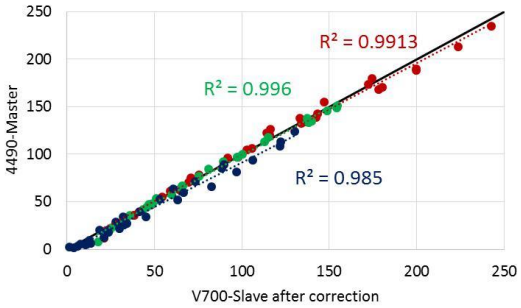


Figure 3 : Comparison on the Munsell H10R pattern

"SNAPSHOT" CHARACTERIZATION OF INDUSTRIAL RIVERS

M.N. Pons, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

A. Assaad, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

Key words (5 at the most)

Dissolved organic matter, Industrial pollution, Sulfates, Synchronous fluorescence (2.5, 4.6)

Research question (or operational application)

Rivers flowing though heavily industrialized watersheds carries the signature (and the pollution) of past and actual activities. The North of the Lorraine region in France is crossed by such rivers (Orne, Fensch, Rosselle for example). Many activities such as mining (coal, iron ore) and steel milling have been stopped and some of the rivers have been or are currently restored (polluted sediment dredging, riverbed meandering, etc.). "snapshot" campaigns enable to have a close look to the pollution sources along a watercourse as the distance between sampling stations is short. This methodology has been used to compare two industrial rivers: the Orne River (which restoration started in 1970) and the Fensch River, both tributaries of the Moselle River.

Originality of this work

The "snapshot" methodology enables to have a more refined spatial monitoring of the watercourse than the Rhin-Meuse Water Board. However the latter is complementary, as it started in 1992.

Data and / or method

Samples have been collected from road and foot bridges (when easily reachable) along the Fensch River, the Orne River and its main (sub)tributaries (Longeau River, Yron River and Woigot River). The samples are analyzed for their dissolved organic matter as well as mineral content (Ca, Mg, Na, K, chlorides, sulfates, ammonium and nitrates). Absorbance spectra as well as fluorescence synchronous spectra (with a 50 nm gap between excitation and emission) are collected.

Main results

The spatial monitoring enables to detect the main breakpoints in terms of surface water quality. The effect of mine water pumping to maintain the rivers flowrates is clearly visible with an increase of the conductivity and of the sulfates concentrations near the former mining sites. The fluorescence spectra collected along the Orne River exhibit typical bands related to protein-like substances and humic-like substances. A change is the relative importance of protein-like fluorescence with respect to humic-like fluorescence is noticeable downstream of Auboué, when the industrial land cover increases with respect tothe more agricultural land cover observed in the upstream part of the watershed. For the Fensch River the spectra collected downstream the industrial activities do not present

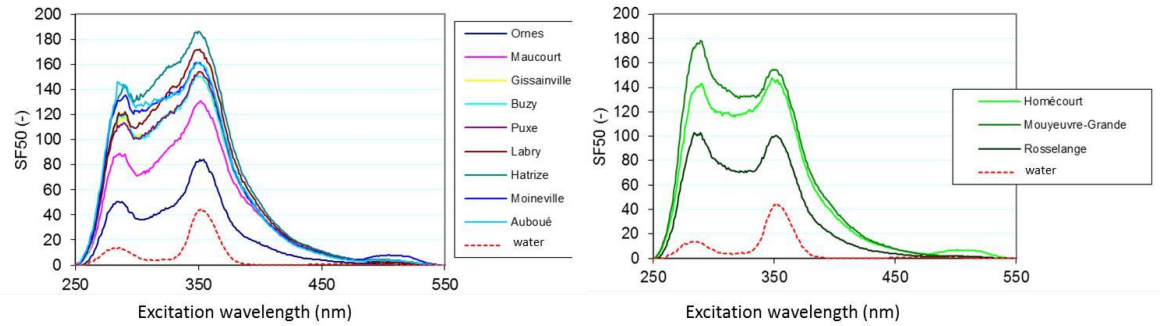


Figure 1: Synchronous fluorescence spectra along the Orne River, from Ornes (source) to Rosselange

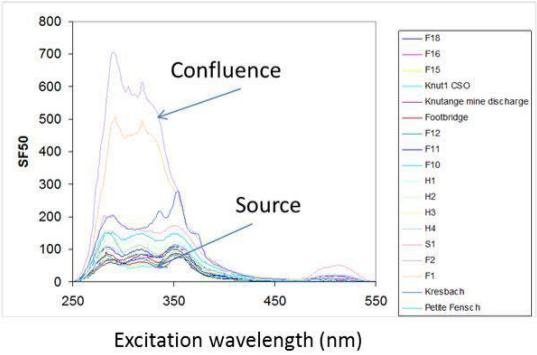


Figure 2: Synchronous fluorescence spectra along the Fensch River

"SNAPSHOT " CHARACTERISATION OF INDUSTRIAL RIVERS

Aziz Assaad, M.N. Pons

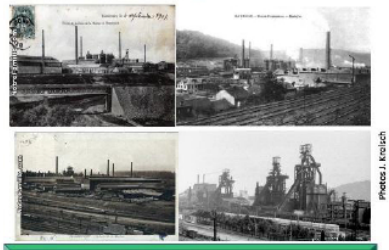
Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine,
1 rue Grandville, BP 20451, 54001, Nancy cedex, France

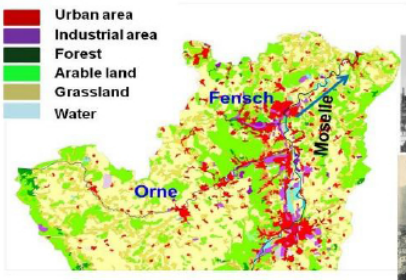
Introduction

During the XIXth century, in the Northern region of France as well as in Belgium, Luxembourg or Germany, large industrial activities were developed based on coal and iron mines and steel milling. The mines are now closed in France and steel industry has been declining for the last thirty years leading to the existence of many brownfield sites. Even during the golden ages of these industrial activities, protection of the aquatic environment was not a key issue and many rivers still bear scars of this behavior. In Lorraine, some of these rivers are tributaries of the Moselle River (Fensch River, Orne River, etc.). Their water and sediments are often polluted by PAHs and heavy metals. Furthermore the rivers received still now badly treated (or untreated) industrial and domestic effluents as well as run-off from brownfields. "Snapshot" campaigns enable to have a close look to the pollution sources along a watercourse as the distance between sampling stations is short. This methodology has been used to compare two industrial rivers: the Orne River (which restoration started in 1970) and the Fensch River.

Study area : Two rivers were studied (figure1): the Orne River which is a left tributary of the Moselle and sub-tributary of the Rhine and it drains a catchment of 1268 km². Its source is in the hills northeast of Verdun. It flows east and joins the Moselle near Mondelange, between Metz and Thionville after a course of 85.8 km. The Fensch River is also a left tributary of the Moselle River and it drains a catchment of 82.8 km². It has its source in Fontoy, and joins the Moselle River in Illange after a course of 13.5 km.

Fensch





Orne

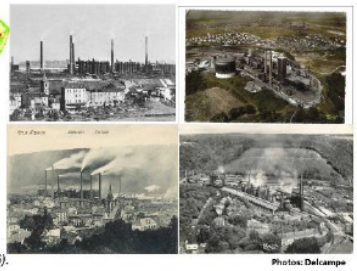


Figure 1: Land use in the two basins (Corine Land Cover 2006).

Photos: Delcampe

Materials and methods

Samples have been collected from road and foot bridges (when easily reachable) along the Fensch River, the Orne River and its main (sub)tributaries (Longeau River, Yron River and Woigot River). The samples are analyzed for their dissolved organic matter as well as mineral content (Ca, Mg, Na, K, chlorides, sulfates, ammonium and nitrates). Absorbance spectra as well as fluorescence synchronous spectra (with a 50 nm gap between excitation and emission) are collected. In terms of fluorescence, synchronous spectra are collected on a F-2500 spectrofluorometer (Hitachi) using a PMMA cuvette. Excitation varies between 230 and 600 nm. Slits of 2.5 nm are used. The photomultiplier voltage has been set at 700V. Ultra-pure water is used for blanking and the Raman water peak is used for standardization.

Results

Fensch

The spatial monitoring enables to detect the main breakpoints in terms of surface water quality. The effect of mine water discharges/run-off is clearly visible with an increase of the conductivity and of the sulfates concentrations (figure 2(a, b)) near the former mining sites.

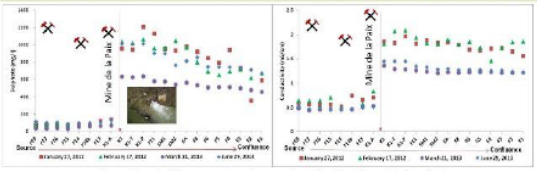


Figure 2a : Sulphate concentrations and conductivity along the Fensch river.

Orne

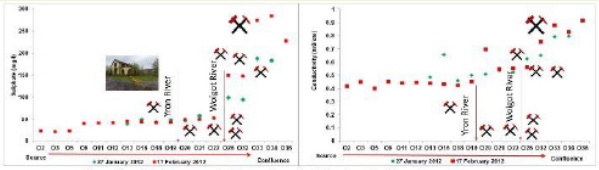


Figure 2b : Sulphate concentrations and conductivity along the Orne river.

Figure 3a shows series of synchronous spectra collected during four different sampling trips along the Fensch River between the source (Fontoy) and the junction with the Moselle River at Illange. In the spectra the closest to the source it is often possible to recognize a peak around λ_{ex} ≈260 nm which can be attributed to tryptophan-like fluorescence related to untreated domestic sewage. However peaks appear downstream which are more difficult to relate to humic substances. By comparison with (pure HAPs in ultra-pure water), it can be assumed that phenanthrene and fluoranthene can be present in the water samples. The fluorescence spectra collected along the Orne River (figure 3b) exhibit typical bands related to protein-like substances and humic-like substances. A change is the relative importance of protein-like fluorescence with respect to humic-like fluorescence is noticeable downstream of Auboué, when the industrial/urban land cover increases with respect to the more agricultural land cover observed in the upstream part of the watershed.

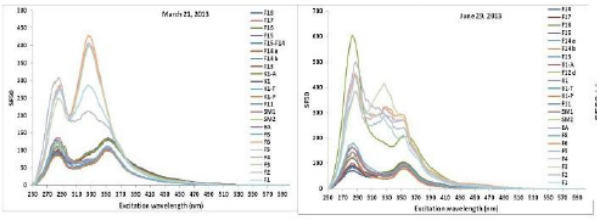


Figure 3a: Series of synchronous spectra collected at different dates along the Fensch river.

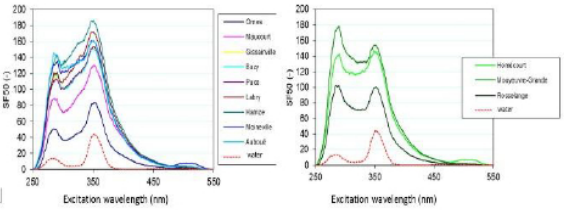


Figure 3b: Synchronous fluorescence spectra along the Orne River, from Ornes (source) to Rosselange

Conclusions

To monitor the improvement of the status of industrial rivers under restoration, sampling campaigns were organized. In addition to the traditional analysis, optical methods (UV-vis and fluorescence spectroscopy) are applied to characterize the dissolved organic matter. The "snapshot" methodology enables to have a more refined spatial monitoring of the watercourse than the Rhin-Meuse Water Board.

Acknowledgements

The authors wish to thank the Zone Atelier du Bassin de la Moselle and the Région Lorraine for their financial support

CHARACTERIZATION OF HYPORHEIC DOM BY OPTICAL METHODS

N. Adouani, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

Y. Zhang, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

A.Assaad, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

M.N. Pons, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

Key words (5 at the most)

Dissolved organic matter, Hyporheic zone, Synchronous fluorescence, UV-vis spectroscopy (2.5, 4.6)

Research question (or operational application)

River hyporheic zone is recognized as an important compartment of aquatic systems butits study is not easy as sampling requires a specific equipment. Dissolved organic matter (DOM) is one of the parameters which enables to understand the functioning of the hyporheic zone. Comparison between surface and hyporheic DOM at two depths (-30 and -50 cm) is discussed based on its optical characteristics obtained by UV-visible spectroscopy and synchronous fluorescence.

Data and / or method

Samples have been collected under different flow conditions and seasons along a 100m long meander of the Brenon River (sub-tributary of the Moselle River). The meander is in the downstream section of the Brenon River, where assimilative capacity has been shown (Zhang, 2015). Hyporheic water was sampled at depth of 30cm and 50 cm using a Bou'Rouch pump. Absorbance spectra as well as fluorescence synchronous spectra (with a 50 nm gap between excitation and emission) were collected and dissolved organic carbon measured.

Main results

Figure 1 shows the example of three samplings (on a riffle zone (point 0) and in a pool –point 8). No difference in terms of absorbance at 254 nm can be seen for each sampling point. The plots differ in the UV zone, mainly due to the nitrates contents. In the pool the nitrates contained in the surface water are not present in the hyporheic zone. In the riffle zone there is an increase in nitrates concentration between the surface and the hyporheic samples. As seen in Figure 2, the synchronous fluorescence spectra for the same samples exhibit similar shape. However, the protein-like fluorescence is slightly higher in the hyporheic zone than in the surface water.

whole set of results will be discussed in two ways:

- After decomposition of the synchronous fluorescence spectra in terms of Gauss functions, corresponding to pseudo-fluorophores

- After Principal Components Analysis of the synchronous fluorescence spectra and building of co-inertia map between surface and hyporheic zone.

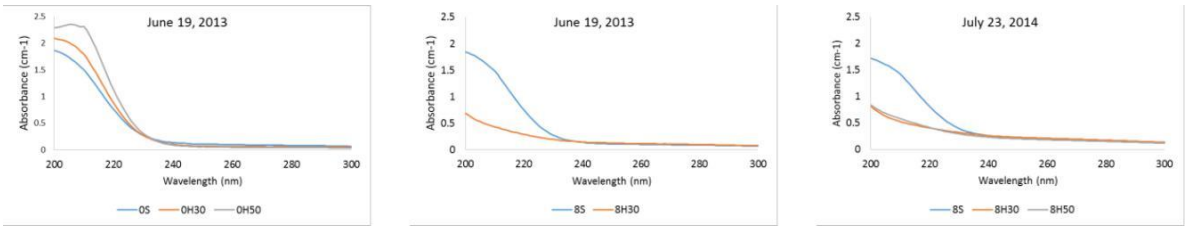


Figure 1: UV-visible absorbance spectra at point 0 (riffle) and point 8 (pool): surface sample (S), at 30 cm depth (H30) and at 50 cm depth (H50)

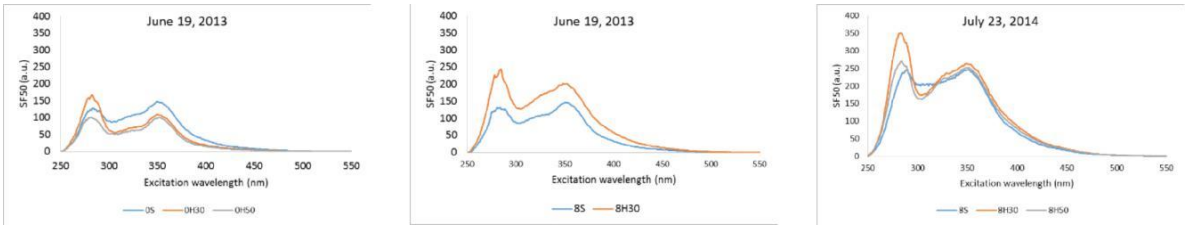


Figure 2: Synchronous fluorescence spectra at point 0 (riffle) and point 8 (pool): surface sample (S), at 30 cm depth (H30) and at 50 cm depth (H50)

CHARACTERIZATION OF HYPORHEIC DOM BY OPTICAL METHODS

N. Adouani, Y. Zhang, A. Assaad, M.N. Pons
Laboratoire Réactions et Génie des Procédés – CNRS, Nancy Université, BP 20451, 54001 Nancy cedex

INTRODUCTION

River hyporheic zone is recognized as an important compartment of aquatic systems but its study is not easy as sampling requires a specific equipment. Dissolved organic matter (DOM) is one of the parameters which enables to understand the functioning of the hyporheic zone. Comparison between surface and hyporheic DOM at two depths (-30 and -50 cm) is discussed based on its optical characteristics obtained by UV-visible spectroscopy and synchronous fluorescence.

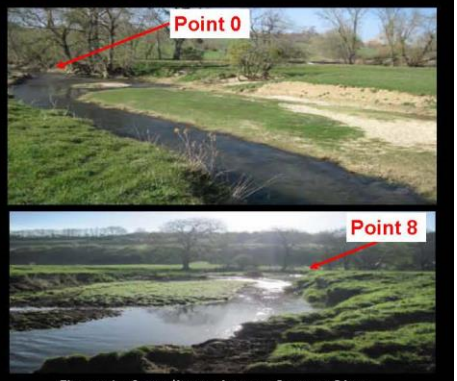
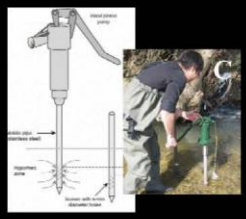


Figure 1 : Sampling points on Brenon River

MATERIAL AND METHODS

Samples have been collected under different flow conditions and seasons along a 100m long meander of the Brenon River (sub-tributary of the Moselle River), through eight sampling points (point0-point8) as shown on Figure 1. The meander (Figure 2) is in the downstream section of the Brenon River, where assimilative capacity has been shown (Zhang, 2015). Hyporheic water was Sampled at depth of 30 cm and 50 cm using a Bou'Rouch pump.



Absorbance spectra as well as fluorescence synchronous spectra (with a 50 nm gap between excitation and emission) were collected and dissolved organic carbon measured.

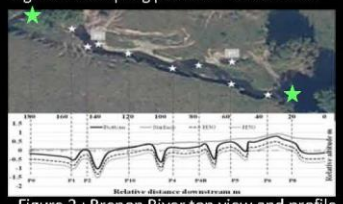


Figure 2 : Brenon River top view and profile along the meander

RESULTS

Figure 3 shows the example of three samplings (on a riffle zone (point 0) and in a pool –point 8). No difference in terms of absorbance at 254 nm can be seen for each sampling point. The plots differ in the UV zone, mainly due to the nitrates contents (Figure 4). In the pool the nitrates contained in the surface water are not present in the hyporheic zone. In the riffle zone there is an increase in nitrates concentration between the surface and the hyporheic samples. The specific UV absorbance at 254 nm and the spectral slope between 275 and 295 nm give information on the nature of the dissolved organic carbon.

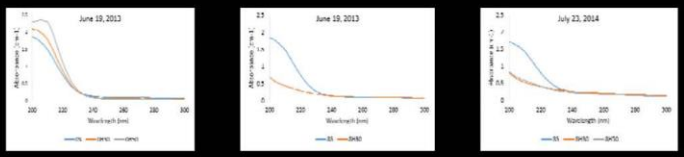


Figure 3 : UV-visible absorbance spectra at point 0 (riffle) and point 8 (pool): surface sample (S), at 30 cm depth (H30) and at 50 cm depth (H50)

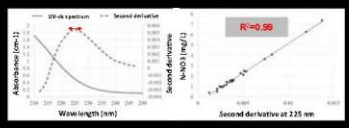


Figure 4 : Relation between nitrates concentration and the UV-vis second derivative

Figure 5 shows that the synchronous fluorescence spectra for the same samples exhibit similar shape. However, the protein-like fluorescence is slightly higher in the hyporheic zone than in the surface water, indicating a higher microbial activity.

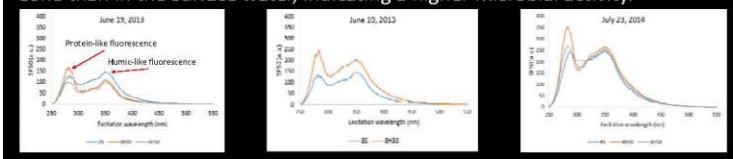


Figure 5: Synchronous fluorescence spectra at point 0 (riffle) and point 8 (pool): surface sample (S), at 30 cm depth (H30) and at 50 cm depth (H50)

		$SUVA_{254}$ ($L.mg^{-1}.m^{-1}$)	$S_{275-295}$ (nm^{-1})	R^2 ($S_{275-295}$)
June 19, 2013	0S	2.54	0.009	0.97
	0H30	1.42	0.007	0.80
	0H50	1.16	0.005	0.48
	8S	2.48	0.009	0.98
	8H30	1.24	0.013	0.96
July 23, 2014	8S	3.01	0.011	0.99
	8H30	1.69	0.012	0.99
	8H50	1.69	0.011	0.99

High $SUVA_{254}$ = high aromaticity
High $S_{275-295}$ = high molecular weight
(see Guéguen et al., 2012)

CONCLUSION

Optical methods (UV-visible spectroscopy and synchronous fluorescence spectroscopy) are environmentally-friendly methods that that can help to monitor dissolved organic matter in surface water as well as in hyporheic matter. Further work is however necessary to achieve a better understanding of the phenomena occuring in hyporheic zones.

ACKNOWLEDGEMENTS

These results were obtained in the course of the EPEC project (ECOTECH N° ANR-10-ECOT-007-01).
A financial support of ZAM and Région Lorraine is acknowledged

OXYGENATION IN WATER CASCADES: EXPERIMENTS AND MODELLING

O. Potier, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

H. Khdhiri, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

J.P. Leclerc, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

M.N. Pons, Laboratoire Réactions et Génie des Procédés (UMR 7274 CNRS), Université de Lorraine, 1 rue Grandville, BP 20451, 54001, Nancy cedex, France

Key words (5 at the most) : *CFD, Cascade, Correlation, Mass transfer, Oxygenation, (2, 24))*

Research question (or operational application)

The oxygen concentration is one of the parameters the most cited in terms of surface water quality as it is an essential element in the chemical and biological processes involved in the degradation of pollution. The oxygen present in atmosphere is soluble in water in function of its partial pressure in the gas phase, its concentration in water. Its solubility is higher at low temperature. Oxygen enrichment can be obtained by physical mechanisms of mass transfer between air and water. These mechanisms are induced by the oxygen concentration gradient. To favor the aeration of natural surface water, it is possible to create special bed shapes, such as a single step or a series of steps (cascade). The question is how to select these shapes while keeping in mind the other constraints such as accessibility by wildlife (fish, etc.).

Data and / or method

A pilot has been built in the lab to study the effect of the number and the size (height, length) of the steps (Figure 1). Residence time distributions and oxygen profiles have been measured for different flow conditions. A CFD model has also been built to have a fine representation of the flow patterns.

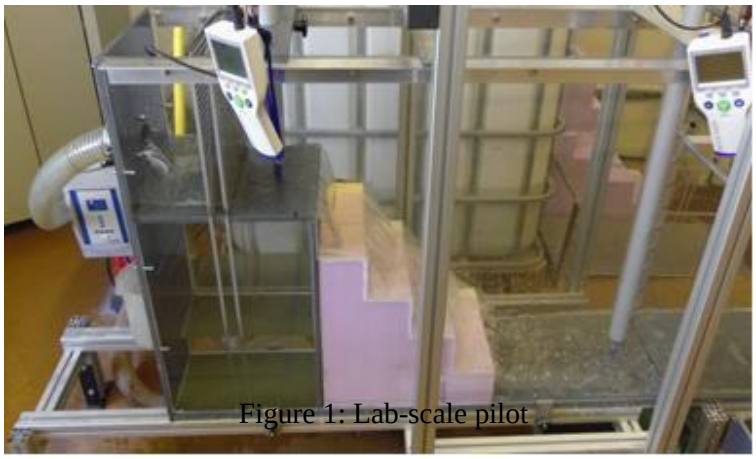


Figure 1: Lab-scale pilot

Main results

Experiments have provided correlations between the oxygenation efficiency, the cascade geometrical characteristics and the flow conditions. CFD simulations helped to understand the motion of the liquid on the steps (Figure 2). Both approaches enable to provide design rules in terms of oxygenation for river restauration and artificial rivers used as fish ladders, etc.

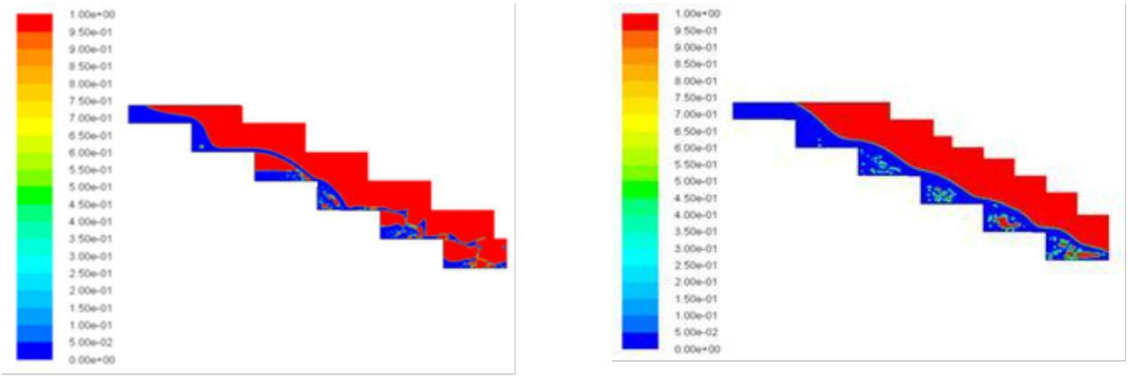


Figure 2: Example of CFD results for a cascade of five steps at low flowrate (left) and high flowrate (right): air volume fraction.

MONITORING OF DRAINAGE SYSTEMS FOR ASSESSMENT OF MATTER TRANSPORT INTO SURFACE WATER BODIES

U. Ulrich, Institute for Natural Resource Conservation, Dep. Hydrology&Water Resources Management, UniversityKiel, uulrich@hydrology.uni-kiel.de
B. Schmalz, Institute for Natural Resource ConservationKiel, Dep. Hydrology&Water Resources Management, University Kiel, bschmalz@hydrology.uni-kiel.de
N. Wu, Institute for Natural Resource Conservation Kiel, Dep.Hydrology&Water Resources Management, University Kiel, nwu@hydrology.uni-kiel.de
N. Fohrer, Institute for Natural Resource Conservation, Dep. Hydrology&Water Resources Management, University Kiel, nfohrer@hydrology.uni-kiel.de

Key words (5 at the most)*(sub-topic 4.5 or maybe 4.1)* Drainage systems, relevant entry pathways, matter transport, pesticides, diatoms

Topic of this work

Drainage systems in agricultural regions have proven to be a relevant entry pathway for matter transport from fields into surface water bodies. Hence, a representative monitoring scheme is essential to gain reliable data for better understanding of processes causing release of matter such as sediment, nutrients or pesticides. This study introducesfour types of drainage system monitoring including sampling and discharge measurements according to diverse scientific issues.

Research question

Do drainage systems significantly contribute to matter transport into surface water bodies? Can temporal and spatial patterns be observed? What is the range of variability between single drainage pipes?Which factors effect relocation of matter to the drainage system? These questions are answered by observation of sediments, nutrients, pesticides and diatoms in drainage systems ofagricultural landscapes.

Originality of this work

In regions with shallow groundwater levels and low hydraulic gradients such as lowlands, drainage systems are a common tool to reduce the soil water content from both, percolating water and rising groundwater. The aeration of soil pores is improved and land-management with heavy agricultural machinery is enabled. The monitoring of drainage systems is still a challenge since access to the pipes and possibilities for technical installations are limited. This study combines several drainage system monitoring concepts with spatial and temporal heterogeneity. The relevance of drainage systems as a contributor for matter input is assessed by the matters mentioned above and diatoms as indicators for drainage water. Furthermore, it is demonstrated that hydrological modelling at catchment scale can be improved by implementation of drainage systems into ecohydrological models.

Data and / or method

Four different types of drainage monitoring such as grab sampling, Venturi-channel and on-site measurements in(tile) drainage system are presented for sediment-, nutrient- , pesticide transport anddiatom composition, respectively.For sediment transport and diatom composition, grab samples were taken twice a weekand weekly, respectively,while for nutrient transport, sampling was carried out

in daily time steps and for pesticide transport, daily mixed samples were taken. Exemplarily, the installations for a monitoring in a manhole of a drainage system are shown in Fig. 1.

Main results

The distinct sampling strategies provided the following answers to the research questions:

Diatom monitoring revealed that *Planothidiumlanceolatum, Fragilaria biceps* and*Naviculagregaria* are dominant in tile drainages, whatis different to the species compositionofstreams in the same catchment. Based on these differences, diatoms could potentially be used as tracers for the separation of single runoff components and therewith, for describing the relevance of drainage systems to the stream flow.Sediment measurements show a high spatial and a lower temporal heterogeneity.The amount of the discharge is assumed to be the major factor causing matter transport. This study gives evidence of a weaker correlation between discharge and transported sediment in [mg/l].Continuous nitrate measurements indicate that besides rainfall patterns the kind of crop and the associated fertilization are the crucial factors influencing nutrient transport to drainage system and then as a short cut to surface water bodies.High resolution on-site monitoring of pesticides show the fast response of drain flow to rainfall events and hence, associated relocation of pesticides. Furthermore,preferential flow could be observed with this sampling scheme causing fast transport to the drain pipe and where physico-chemical properties were of lower relevance for the transport pattern than during transport through bulk soil.

The implementation of drainage systems into hydrological models enables a more realistic simulation of discharge and the water balance of the catchment.

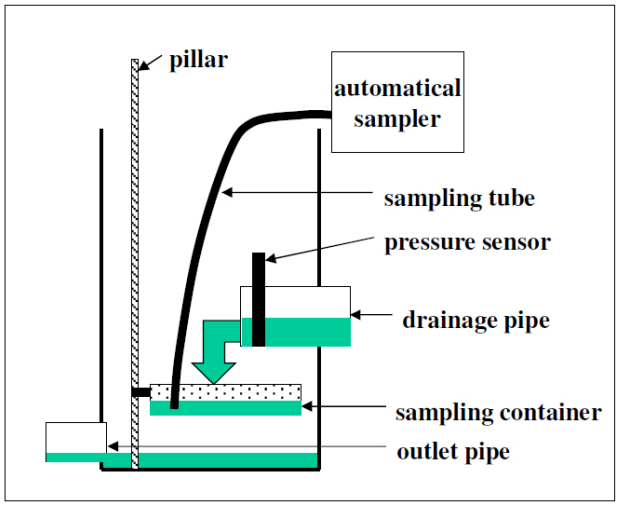


Fig. 1: Technical installations in a manhole for drainflow measurement and pesticide sampling

Discussion

The results show how challenging drainage system monitoring is. Especially the spatial heterogeneity is relevant for the assessment of drainage contributions at catchment scale. Therefore, an individual monitoring concept for the parameters to be observed and each catchment has to be developed to gain reasonable results. Upscaling of results from one drain pipe to larger areas might not be suitable or at least, has to be carried out very carefull

LINKING GEOCHEMICAL AND ECOLOGICAL STATUS IN GROUNDWATER ECOSYSTEMS: INSIGHTS FROM RESIDENT BIOLOGICAL COMMUNITIES

Zoppini Annamaria[1,] (zoppini@irsa.cnr.it),
Amalfitano Stefano[1] (amalfitano@irsa.cnr.it),
Di Lorenzo Tiziana[2] (dilorenzo@ise.cnr.it) ,
Ghergo Stefano[1] (ghergo@irsa.cnr.it),
Lungarini Silvia[1] (lungarini@irsa.cnr.it),
Parrone Daniele[1,3] (parrone@irsa.cnr.it),
Rossi David[1] (rossi@irsa.cnr.it),
Preziosi Elisabetta[1] (preziosi@irsa.cnr.it)

[1] Water Research Institute (IRSA - CNR)- Monterotondo (Rome), Italy,
[2] Insitute of Ecosystem Study (ISE-CNR) - Sesto Fiorentino (Firenze), Italy,
[3] Roma Tre University, Rome, Italy

Key words: *groundwater, biogeochemistry, microbial communities, crustaceans, water quality*

Topic of this work

Biological communities play a key role in the groundwater processes, including the fate of contaminants. The groundwater ecosystems are populated by diverse and highly adapted biota, dominated by microorganisms and invertebrates. These communities provide important ecosystem services and may act as biological indicators of impacts on groundwater resources (Giordano et al. 2009, Amalfitano et al. 2014).

Research question (or operational application)

Despite the qualitative status of groundwaters is a central environmental issue, the monitoring strategies are based almost exclusively on hydrogeochemical parameters. As consequence, there is a significant gap between knowledge of chemical contamination and the impact on ecological diversity and environmental health. Basic research is needed to establish the community structure and functional relationships to understand the effects of environmental stress on these systems.

Originality of this work

A comprehensive study of a water table aquifer flowing through a quaternary volcanic district (Latium Region, central Italy) was performed to link the geochemical status to the biological communities properties. Microbial and crustacean communities were sampled periodically from private wells and springs in an area affected by moderate anthropic impact. The key issues within the sampling area are related to the occurrence of arsenic and fluoride from natural sources. The main microbial features such as microbial biomass, activity and diversity have hardly been considered as biological indicators in the assessment of aquatic ecosystem change. Invertebrate fauna are an important part of the groundwater ecosystems in terms of their position on the food web between microbial and larger organisms. They play the important role in transferring the energy from microbes to higher organisms and are able to change the environment in which they live. The analyses of the microbial and crustaceans communities in the groundwater may contribute to shed more light upon the state and dynamics of such ecosystems.

Data and / or method

Field data included: GPS localization, well depth (m), water table level (m), Eh (mV), T (°C), pH, alkalinity, dissolved oxygen (DO%), conductivity (EC, µS/cm). Chemical parameters (0.45 µm-filtered samples) were measured by Optical Emission Spectroscopy (ICP-OES) for major cations. Inductively

Coupled Plasma Mass Spectrometry (ICP-MS) was used for trace elements. Ionic Cromatography (IC) for major anions. Spectrophotometry for NO_2, PO_4, NH_4. Shimadzu TOC-5000 analyzer for DOC. The Colilert-18 test was used to estimate the occurrence of coliforms and *E. coli* (APHA,AWWA,WEF, 2009). Flow cytometry and epifluorescence microscopy for total prokaryotic abundance and cells with high and low nucleic acid content (HNA, LNA) (Amalfitano et al. 2014). BIOLOG test to describe the metabolic profiles of the microbial communities. Bore water (1m3) was filtered through a 63-µm mesh net and fixed with ethanol 70%. Crustacean specimens were sorted under a stereomicroscope for taxonomic identification.

Main results

The sampled sites were differently affected by natural and anthropogenic factors (arsenic, fluoride and coliform pollution). Differences in the aquifer typologies affect the structure of the free-living bacterial communities that also induce differences in the functional properties. Overall, the total prokaryotic abundance was in the range of 10^3-10^4 cells/ml, with most of cytometric detected cells showing a low nucleic acid content (on average 70% of total cells). The functional properties of microbial communities, as assessed by the BIOLOG test, showed patterns surprisingly different for all the five classes of substrata analyzed (amines/amides, amino acids, carboxylic acids, carbohydrates, polymers), implying a high metabolic diversity.
The crustacean communities were constituted by 117 different specimens, belonging to 8 taxa, 6 of which were Stygobionts. Interestingly 4 groundwater samples belonging to the same sector of the aquifer, characterized by lower salinity and sulfate content, harbored no crustacean specimens. The absence of crustaceans was linked to higher metabolic rates of the microbial communities determined by the BIOLOG test.

Discussion

These preliminary results may represent an important step to build a tool for the groundwater management and preservation. Differences in the microbial/crustacean communities imply responses by resident communities to environmental changes, including natural and/or anthropic pressures. These observations deserve further in depth investigation as this approach seems to be appropriate for a better understanding the link between groundwater quality and biological properties in the definition of the good environmental status.

References

Amalfitano, S., Del Bon, A., Zoppini, A., Ghergo, S., Fazi, S., Parrone, D., Casella, P., Stano, F., Preziosi, E, 2014. Groundwater geochemistry and microbial community structure in the aquifer transition from volcanic to alluvial areas. Water Research 65, 384 -394

APHA, AWWA, WEF, (American Public Health Association, American Water Works Association, Water Environment Federation), 2009. Standard Methods for Examination of Water and wastewater. XXI Ed. Washington, DC, US.

Giordano, M., 2009. Global groundwater? Issues and solutions Annual Review of Environment and Resources 34, 153e178.

UNESCO Ecohydrology Demonstration Site Workshop.

WORKSHOP ON ECOHYDROLOGY DEMONSTRATION SITES -SOLUTION ORIENTED AND LATEST ACHIEVEMENTS FOLLOWED BY THE LAUNCH OF THE ECOHYDROLOGY WEB PLATFORM

22 SEPTEMBER 2015, LYON, FRANCE

Arduino Giuseppe
Programme Specialist
Division of Water Sciences
International Hydrological Programme (IHP)
UNESCO

7 Place de Fontenoy, 75007 Paris, France
Tel: +33 (0) 1 45 68 39 99
Fax: +33 (0) 1 45 68 58 11
Email: g.arduino@unesco.org
http://www.unesco.org/water

Since 2011 UNESCO-IHP promotes the establishment of various demonstration sites around the world to apply Ecohydrology solutions in watersheds at all scales. One of the main goals of the present workshop is to share the current development in solution-oriented methodologies and achievements at site level, as well as to revitalize the network and promote further cooperation among the same demonstration sites and disseminate the acquired information to UNESCO's Member States and the general public. The workshop will be attended by 14 countries (Argentina, Australia, China, Croatia, Ethiopia, France, Germany, Kenya, Indonesia, Italy, Malaysia, Philippines, Poland, Portugal), each one presenting ecohydrological demonstration sites. Different case studies applying ecohydrological solutions dealing with issues such as nutrients concentrations, water purification, diverse aquatic habitats like wetlands, marshes, mangroves, cyanobacterial blooms, among others, in order to find long-term solutions integrating social components, will be presented.

The demonstration sites integrate the concept of enhanced ecosystem potential with ecohydrological strategies to achieve sustainability of ecosystems closely related with water to improve IWRM on specific areas. This is termed WBSR (w-water, b-biodiversity, s-ecosystem services, and r-resilience) containing the four elements that should be taken into consideration while trying to improve the ecosystems potential.

The web-platform to be launched during this event is the interactive environment that will enhance the dissemination of the ecohydrological concept within different targets, from scientists to general public and to Member States. The web-platform contains information about the current demonstration sites, their main description, outcomes and results obtained; it also shows the major ecohydrology events to come, as well as funding opportunities and a link to apply to the Ecohydrology network. Application to become a UNESCO EH Demonstration site will be done through the web platform and "demo cards" will be constructed through an automatic user friendly process.

ECOHYDROLOGY APPROACH FOR MANAGING PUTRAJAYA LAKEAND WETLANDS IN MALAYSIA: THREATS AND OPPORTUNITIESFOR A SUSTAINABLE DEVELOPMENT

[1]Rahmah Elfithri, Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor, Malaysia, elfith@ukm.edu.my
[2]Mazlin Bin Mokhtar, Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor, Malaysia, mazlin@ukm.edu.my
[3]Normaliza Nordin, Putrajaya Corporation (PPj), Putrajaya, Malaysia, liza@ppj.gov.my
[4]Nurliyana Abdul Rahman, Putrajaya Corporation (PPj), Putrajaya, Malaysia, liyana@ppj.gov.my

Key words (5 at the most) : ecohydrology, putrajaya, lake, wetlands, sustainable development

Topic of this work

The paper highlights approaches taken in managing lake and wetlands in Putrajaya, Malaysia based on theEcohydrologyprinciplestowards achievingSustainable Putrajaya 2025 (i.etransformingPutrajayafrom a Garden City to a Green City),as well as initiatives that have been done to ensure its sustainability.

Research question (or operational application)

The specific research questions or the operational applications that is of concern in this paper are as follow:

1) Ecohydrology Approach –How it was used and implemented in Putrajaya, and how effective is it?
2) Initiatives towards achieving sustainable development – Is there any specific program to educate and bring about awareness and understanding on water and environmental sustainability for Putrajaya Community?
3) Stakeholders and local community engagement – How they were linked and cooperated among each other? Any specific platform or method for engagement?
4) Other intervention in Putrajaya such as Ecohydrology Demo Site status, Ecotourism activities, Recreation, Fishing, Centre for water sports, Water transport,etc – How to sustain and better manage towards achieving sustainable development of Putrajaya (Sustainable Putrajaya 2025), Putrajaya Green City 2025 (PGC2025), integrated catchment management of lake and wetlands, etc.

Originality of this work

The works presented in this paper were carried out based on previous studies conducted, lesson learned, feedback received, observation, and direct involvement in Ecohydrology application, management and conservation of Putrajaya Lake and Wetlands. The wetlands and the lake have been developing an interesting urban ecosystem that has enhanced the ecosystem services in the areas. There is a need for balancing stakeholders' needs and ecological planning. Currently, public in

general are not yet understand what is the meaning of Ecohydrology and its application. Many people are not appreciating the current available elements that are well enjoyed by them as present generations, from the current environmental resources and services. They are taking for granted on the resourcesavailability in Putrajaya without concerning the future-oriented aspects by conserving and taking care the environment, including the lake and wetlands for their future generations. The operational challenges facing in implementing Ecohydrology approach in Putrajaya technically were due to lack of expertise and knowledge on Ecohydrology, on how to effectively apply this Ecohydrology into lake and wetlands management and how other works carried so far can compliments to each others. Socially itis also challenging on how to bringpeople to work together in managing and conserving the lake, to raise awareness and to educate them.

Data and / or method

The ecohydrological approach is implemented by the use of constructed wetland as a natural treatment system to treat primary upstream inflow to the lake. The wetland is to be complemented by riparian parks and gross pollutant traps which act in a synergistic way to improve and stabilize the lake water quality. The hydrotechnicalinsfrastructure (e.g., dams, sewage treatment plants, sedimentation ponds, Rock Revetment, Rock weir, OGGT) were also developed to harmonize the ecohydrological measures in this lake catchment.The main objectives for implementing such approaches are to bring together stakeholders and community to be involved in the management and conservation of the lake and wetlands in Putrajaya through increasing stakeholder engagement and community participation, creating awareness, sense of belonging and ownership among communities especially young generation; and educating people to be more responsible in taking care the environment.Some initiatives have been done through various activities in Putrajaya such as initiative in transformingPutrajayafrom a Garden City to a Green City (Putrajaya Structure Plan – SustainablePutrajya 2025), Local Agenda 21 – a Community Programme for Sustainable Development, Development of Nature Interpretive Centre (NIC) atWetland Park Putrajaya, Monitoring, Surveillance, and Maintenance Works of Lake and Wetlands, Environment&EcosystemEducational Programmes (3EP), HealthyCommunityHealthyEcosystem (HCHE), Series of Putrajaya Lake and Wetland Management Workshop/Seminar/Forum/Dialogue/Colloquium, Series of Putrajaya Lake and Wetlands Explorace, Series of Workshop & Photography Contest on Biodiversity Appreciation, Series of Catch and Release Fishing Competition and Series of Bird Watching and Identification Programme.

Main results

The ecohydrological approach that combining the need of the ecosystem into the overall planning, approval, monitoring and enforcement jurisdiction of the city development and the human activities in this catchment area, significantly having a direct impact to the Putrajaya Lake.A number of monitoring and surveillance conducted in this area has shown very positive signs of interesting habitat development and ecosystem enhancement. Water quality is needed to remain in good water quality for allowing water related activities to be conducted in the lake, in line with the National Lake Vision i.e :*"To manage the lake in order to ensure its aesthetic viability, sustain good water quality, and allow for different recreational uses, including primary and secondary contact activities".* They are some problems in implementing an effective catchment management. Studies of the Putrajaya catchment showed that the water carried elevated level of pollutants derived from upstream sources and outside of the Putrajaya development boundary. As a result, the Putrajaya Lake and Wetland Catchment system need to be continuously maintained by using the various new mechanismsfor an effective and best result to ensure the quantity as well as the high water quality

level of the lake is achievable. Future development of the catchment is expected to increase run-off pollutant concentration it is expected to result in increased pollutant loadings in which drain into the Putrajaya Lake. Development projects and the developed areas (populated areas) within Putrajaya boundaries, which occupies about 60% of the Lake catchment areas, need to be monitored more rigorously to ensure compliance to the PutrajayaMasterplan and stringent regulatory enforced by the PutrajayaCorporation (PPj)i.ethe local authority who authorized the management of Putrajaya Lake and Wetlands. For the remaining 40% of the same catchment areas but located in the upstream, outside the Putrajaya boundaries (in the state of Selangor), the collaboration approach has been applied by PPj with various parties in the areas.There are also issues related to habitat degradation in Putrajaya, i.e which regards to Flora and Fauna of the Lake and Wetlands (Diversity of Bird, Fish and other Aquatic life, Terrestrial Fauna).Last but not least, it is also found some issues related to Lack of Participation and Empowermenti.e regarding to Community Participation andStakeholder Engagement in Management of lake and wetlands in Putrajaya.The main expectedoutcome of applying the ecohydrologyapproachintoPutrajaya Lake and Wetlandsis the improvement of the water quality of the surface runoffs flowing into the lake from the upstream areas for its aesthetic viability.

Discussion

Ecohydrology approach has been implemented in managing water resources in Putrajaya which involves integrated management of Putrajaya Lake and Wetland's Catchment which are located partly in Putrajaya

Federal Territory and partly in the State of Selangor, within the Langat River Basin. The catchment has been acknowledge as one of the UNESCO-IHP Ecohydrology Demonstration Project since 2010 and has classified as Operational Site. This catchment's management has implemented a serious and systematic approach and control in order to achieve a sustainable development of Putrajaya. The Lake is an urban lake, created right in the middle of Putrajaya, which is the newly developed Government Administrative Center of Malaysia, which was planned to be developed into a "City in a Garden" with various components such as residential, commercial, public spaces, educational institutions and etc. It is now transformedinto a Green City by 2025.The ecohydrology implementation principles were identified and explored, and it wereimplementedby PPj and were monitored and assessed. The stakeholders involved in the management of Putrajaya Lake and Wetlands were also identified and consulted, among of them were involved some government bodies, private sectors, universities/researchers, local authoritiesand community/individualownership.Activities involving the community participations, such as, involving them in the management and the monitoring exercises are being conducted together with the schoolchildren throughout the year. Actions and programmes are also being worked closely with the all related stakeholders in Putrajaya catchment in bringing people to love the Putrajaya Lake and Wetlands ecosystem.

Aknowledgements

The authors would like to express appreciation to UNESCO-IHP Ecohydrology, UNESCO Office Jakarta, UNESCO-IHP Malaysia, Putrajaya Corporation (PPj), Integrated Water Resources Management (IWRM) Research Group & Sustainable Ecosystem Management Research Group of UKMfor knowledge contribution and technical or financialsupports givenduring the study on EcohydrologyApproach at Putrajaya Demo Site, and also the Institute for Environment and Development (LESTARI), UKM for bringing Putrajaya Lake and Wetlands as one of the UNESCO-IHP Ecohydrology Demo Site Networks.

A FIELD OBSERVATORY FOR URBAN WATER MANAGEMENT

Barraud Sylvie, University of Lyon, INSA Lyon, LGCIE-DEEP, F-69621 Villeurbanne cedex, France, sylvie.barraud@insa-lyon.fr

Bacot Laëtitia, GRAIE - Groupe de Recherche Rhone-Alpes sur les Infrastructures et l'Eau, Villeurbanne, France, laetitia.bacot@graie.org

Breil Pascal, Irstea, UR HHLY, 5 rue de la Doua, F-69100, Villeurbanne, France, Pascal.breil@irstea.fr

Lipeme Kouyi Gislain, University of Lyon, INSA Lyon, LGCIE-DEEP, F-69621 Villeurbanne cedex, France, gislain.lipeme-kouyi@insa-lyon.fr

Cottet Marylise, Chargée de recherche CNRS, UMR 5600 "Environnement Ville Société", ENS de Lyon, bureau R 243, 15 parvis René Descartes, 69007 LYON

Namour Philippe University of Lyon, Université Claude Bernard Lyon 1, Institute of Analytical Sciences, UMR 5280, 5 rue de la Doua, F-69100, Villeurbanne, France, philippe.namour@isa-lyon.fr

Key words: Field observatory, (peri)urban water cycle, multidisciplinary approach, storm-water management, receiving water management.

Background

Practitioners and utilities expect urban planning tools and procedure, particularly for adapting their assets to (i) a rapidly evolving urban fabric, (ii) a more constraining environmental policy and also (iii) the predicted climate change which should make the sewer system to overflow more frequently and reduce the dilution capacity of the natural receiving water system. Opportunities for testing new management practices can take place during urban retrofitting program and the peri-urban development. However, investigations based on long-term series data are often limited by the cost of monitoring systems and metrological equipment. In this context, the OTHU program has been developed since 1999. It is mainly based on experimental catchments that are representative of a gradient of urban environments. A continuous and intensive monitoring is carried out in line and on the key compartments of the water cycle, from the atmosphere to the receiving water systems.

The OTHU (French acronym for Observatoire de Terrain en Hydrologie Urbaine) is a long term outdoor monitoring project, aiming to understand the processes and mechanisms involved in the interaction between the urban water cycle and the issued and conveyed pollution in urbanized areas. Its main operational goal is to better manage the urban water cycle and protect the receiving water systems. Due to the large spatial and temporal variability of the related fluxes, the interactions between abiotic and biotic components of the urban water cycle are complex to model. Long time series of data are then necessary to identify their driving forces. The social dimension of environmental challenge is also considered in the monitoring because the willingness for change is also a driving force that must be integrated in the decision making process of urban managers.

Research objectives

The OTHU research focuses on the different processes involved in the water cycle in urbanized areas in particular as a response to rain events. These processes are examined from various points of view including physical (water transfer), chemical, biological, pathogenic, ecological aspects (source, transfer, transformation and impact of pollutants / contaminants found in urban water from

atmosphere to aquatic systems (water courses and groundwater). It pursues the following scientific objectives:

- ✓ The improvement and development of existing and new monitoring systems deployed in drainage systems and receiving water bodies, as the key element for the management strategy;
- ✓ A better knowledge on rainfall and climatology at the urban scale, and the related factors that increase flooding and pollution risks;
- ✓ A precise measure on water and pollutants production and transfer during dry and wet weather;
- ✓ The assessment of physical, chemical and biological transformations and fate of pollutants in urban water systems (sewer and drainage systems including specific observation of retention and infiltration basins) and receiving water bodies (e.g. receiving water courses and ground water);
- ✓ The development and verification of models able to simulate pollutants transport and transformation through urban water systems;
- ✓ The development of decision making tools to enhance performance of stormwater management infrastructures and of receiving water bodies.

The observatory also gives rise to economic and social benefits related to:

- ✓ The improvement of the quality of natural waters and protection of water resources;
- ✓ The reduction of flooding and drought risks managing excess runoff and seepage waters;
- ✓ The reduction of the costs linked to the implementation and operation of urban drainage systems,
- ✓ A better water integration in the urban landscape.

Originality of this work

The OTHU represents an original research tool bringing new insights on the interaction between conveyed contaminants and the urban water cycle. In addition, interdisciplinary approaches carried out by 15 research groups support the OTHU program. The OTHU network gathers 9 research institutes which are INSA de Lyon, the Universities of Lyon 1, Lyon 2 and Lyon 3, BRGM, IRSTEA-Lyon, Ecole Centrale de Lyon, ENTPE and VetAgroSup. It is supported by the Greater Lyon council and the water basin agency Rhône-Méditerranée-Corse. The commitment was renewed in 2014 for 4 years in order to develop and enhance the observation and research programs based on the observatory's data. The investment in monitoring equipment since the implementation of the OTHU network is of more than 1.7 M€. The mean annual budget of OTHU is of about 2.3 M€.

Experimental sites and demo-sites

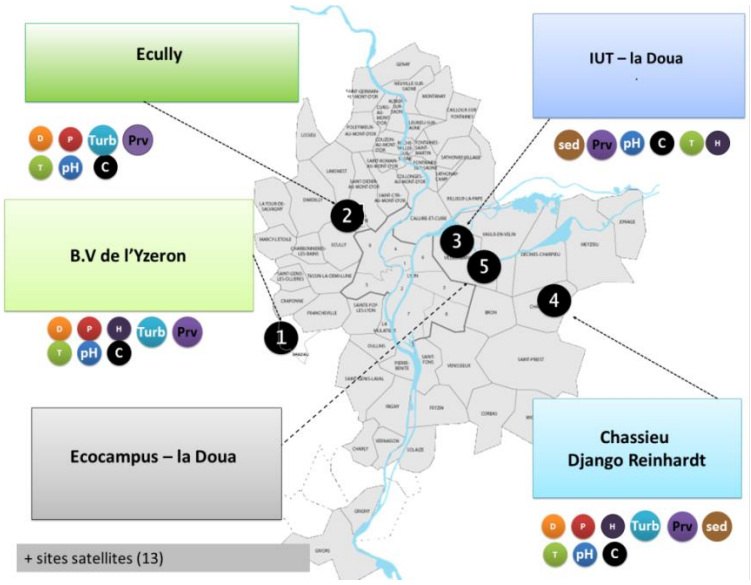


Figure 1: Othu field sites

As the OTHU is an outdoor experimental platform, it relies on experimental sites spread over a gradient of urban pressure impacting two types of water masses. The Western part of Lyon is composed of hilly lands drained by a dense network of small water courses exposed to combined sewer overflows. It is known to be sensitive to the urban storm water impacts and to the diversion of ground water resource by the sewer system defects. The Eastern part is a flat alluvial land with no developed stream network and where the urban runoff is managed using detention basins. The drivers are the gradient of urban pressure which increases from the periurban boundary to the center of the city but also the rapidly developing periurban area which can induce severe degradation on sensitive water masses. The experimental sites are indicated and described in Figure 1 and table 1 respectively.

Table 1: description of OTHU sites

Sites	Kind of watersheds	Drainage system	Sites affected by the system
❶Grezieu la Varenne / Pollionnay	Peri-urban	Combined sewer network	Frequent CSOs damaging physical and chemical habitat features « La Chaudanne » small river
❷ Ecully	Moderately dense urban area (housing)	In great part with combined sewer network	Many overflows through sewer overflow structures into "Trouillat" small river
❸IUT A - La DOUA (Villeurbanne)	Dense urban area (university activities)	Sanitary sewer network with an infiltration basin as outlet structure	Discharge in a not very deep table (Non saturated zone lower than 1 m)
❹ Chassieu - Django Reinhardt	Dense urban area (industrial activity)	Sanitary sewer network with a detention / infiltration basin as outlet structure	Discharge in a deep table (Non saturated zone: about 13 m)
❺ Ecocampus	Dense urban area (university activity)	Study of the flow of water and pollutants, biodiversity produced by a BV provided innovative alternative techniques for stormwater management (green roofs, pavements tank...)	Discharge in a not very deep table (Non saturated zone lower than 1 m)

The experimental sites are also used to monitor and implement true scale pilots (demonstration sites). As an example, the development of a series of artificial porous steps has been implemented at site 1. The objective was to enhance the local self-purification capacity of a small stream exposed to frequent CSOs resulting from the rapid urban development. The 4-years project concluded on a true efficiency of the system to trap and degrade the organic pollution delivered by CSOs during the low flow season. The principle is now in its modeling phase for dedicated sizing of the porous steps and should be generalize in the future to complement the weak natural self-purification capacity of several part of the hydrographic network.

Main results

The observatory was implemented in 1999. Reliable data are available since year 2000. The significant results obtained since 2001 include following insights:

- Analysis of infiltration tank influence on groundwater, thanks to an original physical, chemical and biological monitoring (Marmonier et al., 2013)
- Technical, economical, and environmental performance indicators for infiltration basin in urban areas (Moura et al., 2011)
- Modelling of peri-urban catchment behavior according to rainfall events and land uses analysis (Braud et al., 2013).
- Monitoring system for the impacts of sewer overflow structures on small peri-urban watercourses (Lavenir et al., 2014
- Hydrogeomorphic adjustments of stream channels disturbed by urban runoff (Navratil et al., 2013)
- Identification of geomorphic drivers structuring the pollutant accumulation zones (hot spots) in a periurban stream (Namour et al. 2015).
- The Ecohydrological principle applied to the management of the urban storm water impact (Wagner & Breil, 2013)
- Development of an original monitoring system (see figures 2 and 3). Each monitoring station is equipped identically: strainer; peristaltic pump and measuring channel. A strainer protects the pump from large elements size. It is placed in a picking chute rejection of the CSO, and disposed directly in the river to the upstream and downstream stations. A peristaltic pump PCM Delasco DL45, with a maximum flow of 9.5m^3/h, fed at a rate of 1.5l/s the measuring channel. It transfers the fluid vein by increments avoiding mixing and oxygenation of water, unlike turbo pumps. It is controlled by a water level detector located in the CSO sampling chute. As soon as the water depth exceeds 1 cm in the CSO, the pumps of the three bungalows feed their channel either in river water (upstream and downstream bungalows) or discharged wastewater (CSO bungalow). Each bungalow is equipped with sensors (pH, electrical conductiviy, turbidity and dissolved oxygen), to qualify and to continuously monitor the rainfall events.

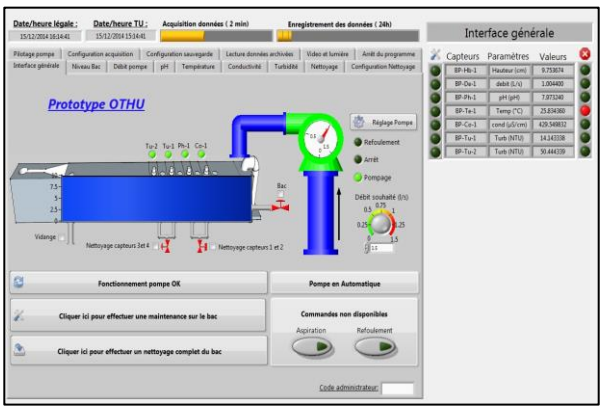


Figure 2: Data processing and implementation Software

Figure 3: measurement flume

The OTHU network also provides to the attention of managers a collection of technical notes which are available on line for free and regularly updated (http://www.graie.org/othu/index.htm). The range of topics they cover is indicated by their titles listed hereunder:

- Measures of soil pollution resulting from discharges of urban wet weather (2002)
- Uncertainty of flow measurement and taken into account in the model calibration (2002)
- Assessment and monitoring of the ecological status of a suburban creek subject to urban discharges of rain (2002)
- The VIGILANCE database of Grand Lyon (2002)
- Automatic pre-validation of environmental data in urban hydrology (2002)
- Experimental Plan for measuring the impacts of stormwater infiltration on the physico-chemical and biological quality of groundwater in urban areas. (2005)
- Metrology Course and Data Quality (2002)
- Characterization of infiltration basin funds new physicochemical and microbiological parameters (2005)
- Performance indicators of stormwater infiltration remediation strategies - Critical Analysis (2005)
- Performance indicators of rainwater drainage infiltration strategies (2011) & Critical Analysis (2009)
- Auto purification of urban discharges wet weather by infiltration basins (2005)
- Elements of the blockage of stormwater infiltration works (2005)
- New Elements in the clogging of stormwater infiltration works (2009)
- Micro-sensors for assessing the chemical status of small peri-urban rivers (2007)
- Microwave sensors for evaluation of chemical water quality (2009)
- Method of estimating the plan amendment flood due to urbanization (2011)
- A hydro-geomorphological typology method of stream reference states towards a management tool suburban Hydraulics
- Towards a methodology for the study of the natural vegetation of infiltration basins (2009)
- Infiltration Trenches (2009)
- Evaluation of the unusual rainy hazard (2009)
- Hydrodynamic holding / settling ponds Behavior (2009)
- Accumulation of metals in the infiltration of storm water basins (2009)
- Improving sewage tailings management processes - Pretreatment of sewage tailings ponds and infiltration (2009)
- Impact of artificial infiltration of rainwater on the functioning of aquifers implications for management (2010)
- Delineation of a watershed suburban and identification of its drainage network (2011)
- Trend analysis methodologies for long hydrometeorological series (2011)
- The land cover mapping methods and trends for monitoring hydrological phenomena of suburban watersheds (2011)
- Regional Foresight methods to simulate changes in the future land use applied to a peri-urban catchment (2011)
- Method of estimation uncertainty on rating curves (2012)

The OTHU organizes a two years technical-days event to the attention of urban water managers, decision makers and scientists working in this area.

Conclusion & perspectives

The OTHU has implemented an active research in the field of the interaction between the urban water cycle and the issued and conveyed pollution in urbanized areas. Some developments are still required. More especially, there is a need to develop researches regarding the social dimension of this question.
This one is in practice broken down into multiple issues relating to the social field (management of flood and sanitary risks, preservation or restoration of ecosystem services produced by urban rivers…). This multiplicity of issues requires implementing an integrated management that involves a large diversity of stakeholders. Those ones have different status and/or missions and consequently, have often different perceptions regarding priorities and modalities of action. The question of stakeholders' participation is thus of prime interest for defining an integrated management of urban waters and requires further researches:

(1) who are those stakeholders? Are political and socio-economical stakeholders associated to the definition of action regarding urban waters? Is the public taken into account? How, and what for?

(2) What are the perceptions, uses, attitudes and expectations of these different stakeholders regarding urban waters? Are these expectations compatible or conflicting and how to technically or socially innovate in order to better conjugate them?

(3) How are the different stakeholders organized and structured? Are there dialogue spaces that favor an interaction between those stakeholders and how to optimize them?

Furthermore, from a more technical point of view, the management of urban waters questions the relationship between urban societies and infrastructures dedicated to the management of urban waters. Can we observe unanticipated uses that may call into question the durability of those infrastructures? And how to better reconcile social uses and expectations with the functioning of urban water infrastructures?
Technical and social innovations that rely on a dialogue between all stakeholders appear to be a way to engage all of them in a willingness for change and to succeed in better managing urban waters.

Aknowledgements

Authors would like to warmly thank all partners and particularly the Grater Lyon and the Rhône-Mediterannée-Corse Water Agency for the financial support. A special agreement has been signed with the Urban Community of Lyon which is a full partner of the project as end-user of the results. The Rhône-Mediterannée-Corse Water Agency, various ministries (Ministry of National Development and Public Works, Ministry of Environmental Protection and Sustainable Development) are also associated with the OTHU Research Federation. At last, other partners who are meant to disseminate the research results (GRAIE, CEREMA) are part of the OTHU project.

References

Braud, I. Breil, P., Thollet, F., Lagouy, M., Branger F., Jacqueminet C., Kermadi S., Michel K.(2013). Evidence of the impact of urbanization on the hydrological regime of a medium-sized periurban catchment in France. Journal of Hydrology ,Vol 485: 5-23. Journal of Hydrology, 485, 5-23.

Lavenir R., Petit S, Ribun S, Loiseau L., Marjolet L. Briolay J., Nazaret S., Cournoyer B. (2014). Structure and fate of a Pseudomonas aeruginosa population originating from a combined sewer and colonizing a wastewater treatment lagoon. Environmental Science and Pollution Research. 2014 Apr;21(8):5402-18. doi: 10.1007/s11356-013-2454-7.

Marmonier P., Maazouzi C., Foulquier A., Navel S., François C., Hervant F., Mermillod-Blondin F., Vieney A., Barraud S., Togola A., Piscart C. (2013). The use of crustaceans as sentinel organisms to evaluate groundwater ecological quality. Ecological Engineering. 57(2013), 118-132.

Moura P., Barraud S., Baptista M.B., Malard F. (2011). Multicriteria decision-aid method for the evaluation of the performance of stormwater infiltration systems over the time. Water Science & Technology, 64 (10), 1993-2000.

Namour Ph., SChmitt L.,EschbacH D., MouliN B.Fantino G., Bordes C., Breil P. (2015) Stream pollution concentration in riffle geomorphic units (Yzeron basin, France), Science of the Total Environment, 532, 80-90.

Navratil O., Breil P., Schmitt L., Grosprêtre L., Albert M.B.(2013). Hydrogeomorphic adjustments of stream channels disturbed by urban runoff (yzeron river basin, France). Journal of Hydrology, Vol. 485: 24-36.

Wagner I., Breil P. (2013). The role of ecohydrology in creating more resilient cities Ecohydrology & Hydrobiology 13 (2013) 113–134. http://dx.doi.org/10.1016/j.ecohyd.2013.06.002

EcoHydrology 2015
Lyon, France, from 21 to 23 September

OTHU

Observatoire de Terrain en Hydrologie Urbaine

Objectives

Get reliable data on the long term of urban wet weather effluents and on their impact on receiving waters, in order to provide results, knowledge and methodologies to assess the sustainability of urban water systems and propose new strategies to manage stormwater in the city.

Objectifs

Acquérir de longues séries de données fiables sur les rejets urbains de temps de pluie et sur leurs impacts sur les milieux récepteurs pour améliorer la connaissance des mécanismes, évaluer les performances et proposer de nouvelles stratégies de gestion des eaux pluviales en milieu urbain

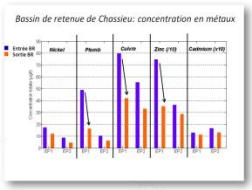

Site expérimental IUT Villeurbanne

A long term and multidisciplinary approach

Climatology, Hydrology, Hydraulics, Soil science, Chemistry, Biology, Hydrobiology, Microbiology, Social science and Economy

Une approche multidisciplinaire sur le long terme

Climatologie, Hydrologie, Hydraulique, Mécanique du sol, Chimie, Biologie, Hydrobiologie, Microbiologie,Sociologie et Economie



A research partnership

- 9 Universities and Engineering Schools
- 12 Research Laboratories, ~110 Researchers
- Main operational partners: the Greater Lyon, Water Agency RMC, Ministry of high education & Research, Rhone-Alps Region

Une Fédération de recherche

- 9 établissements de recherche
- 12 Laboratoires, ~110 Chercheurs
- Partenaires opérationnels principaux : Grand Lyon, Agence de l'Eau RMC, Ministère de l'enseignement supérieur & de la Recherche et Région Rhône-Alpes

Research actions linked to end-users needs

- Rainfall distribution
- Hydraulic and pollutants loads in urban catchments during dry and wet weather
- Impact on the soil, water courses & groundwater
- Interaction between urban and rural areas
- Interaction with citizen practices
- Development of strategies for sustainable urban water management


Site expérimental Minerve – Porte des Alpes

Des recherches structurées par les besoins opérationnels

- Distribution spatio-temporelle de la pluie
- Rejets d'eau et de polluants générés par les bassins versants
- Impact des rejets sur sol, nappe et cours d'eau
- Interaction entre flux urbains et ruraux
- Interactions avec les pratiques urbaines
- Développement de stratégies durables de gestion des eaux urbaines

An original instrument of observation

based on long term monitoring systems, with on-line monitoring sensors and samplers, dedicated to the global assessment of rainfall impact
5 experimental catchments in the area of Lyon representative of

- Urban and péri-urban areas,
- Combined and separate sewers systems,
- CSOs, retention and infiltration tanks, source control system
- Different water bodies: small watercourse and aquifer


Site expérimental Grézieu la Varenne - © T.Fournier

Un instrument original d'observation

basés sur un système métrologique *in situ* et en continu, destiné à l'évaluation globale de l'impact des précipitations
5 sites expérimentaux sur l'agglomération lyonnaise representatifs de :

- Divers modes d'urbanisation
- Réseaux séparatifs et unitaires,
- D.O, bassins d'infiltration et de retenue et contrôle à la source
- Impact sur les petits cours d'eau et les nappes

www.othu.org

A strong effort devoted to results dissemination

- Web site
- Technical sessions for operators (technicians & decision-makers)
- Scientific national workshops
- Periodic meetings between OTHU researchers
- Scientific and technical publications

Une stratégie forte pour la diffusion des résultats

- Site internet
- Journées techniques à destination des opérationnels (techniciens & décideurs)
- Séminaires scientifiques nationaux
- Séminaires entre chercheurs de l'OTHU
- Publications scientifiques et techniques

Scientific partners

INSA Institut National des Sciences Appliquées Lyon
VetAgro Sup
irstea
ENTPE
Université Claude Bernard Lyon 1
brgm Géosciences pour une Terre durable
École Centrale Lyon
Université Jean Moulin Lyon III
Université Lumière Lyon 2

SFR N° 4161

Direction

OTHU SCIENTIFIC DIRECTOR:
Gislain LIPEME-KOUYI, LGCIE-DEEP – INSA Lyon
SFR 4161 DIRECTOR:
Sylvie BARRAUD LGCIE-DEEP - INSA de Lyon

graie **GENERAL SECRETARY OF OTHU**
Laëtitia BACOT- info@othu.org

Institutional partners

GRANDLYON la métropole
agence de l'eau Rhône Méditerranée Corse
Ministère de l'Enseignement Supérieur et de la Recherche
arc Communauté de Recherche Académique Rhône-Alpes
Environnement
Région Rhône-Alpes

Ecohydrological Approaches to resolve the water problems regionally

CASE STUDIES FROM TWO UNESCO DEMO SITES IN CHINA

Demin Zhou, LiliHou, Huili Gong, Xiaojuan LI

UNESCO CHAIR in Hydroinformatics for Ecohydrology

College of Resources, Environment and Tourism, Capital Normal University
105 West Sanhuan North Road, Haidian District, Beijing（100048）
P.R.China Tel: +86-010-6898 0798; Fax: +86-010-6890 3030

Email: zhoudemin@neigae.ac.cn;deminzhou@yahoo.com

Due to the coming challenges caused by both intensive human disturbance and obvious global climate change,it is very significant to use ecohydrological theories and methodologies to present scientific strategies for different kinds of water problems in rural or urban areas. This research presents two key regional ecohydrological problems in both the rural and the urban areas in not only China but also some other developing countries dealing with the water issue, and it also shows the scientific approaches tofix the specific problems by using ecohydrological methodology with Geoinformatic technology supports.

Ecological degradation one local natural marsh wetlands has been observed due to the shortage of environmental flow in an international wetland reserve (Honghe National Nature Reserve, HNNR) in an inland flooding plain in Northeast China.The key issue was caused by the overload water resources transferring from this Ramsar listed wetland ecosystem to the agricultural systemin three surrounding farms. Multiple coupling wetland ecohydrological models quantitatively describe howdifferent wetland plant communities or landscapes respond to the change of environmental flow within the habitats in the catchment scalespatial-temporally.

The other demo site is located in the suburban area of metropolitan Beijing City, which suffersfrom more frequent urban flooding due to more extreme events contributed by global climate changes and more impervious surfaces contributed by urban expansion. However, Beijing City is famous for water resources shortage because the personal water resource takes only one twentieth if comparing with the international standard. The ecohydrological approach in this research firstly presents the wetland landscape shrinkageover the past twenty years spatially with the interpretation of Remote Sensing images. Spatial analysis on ArcGIS helps to delineate potential storm water indicated by one extreme event in 2009, and hydro-geomorphological analysis supported by Digital Elevation Model (DEM) presents further river connection and flooding information. Finally, urban ecohydrological models generate some scientific resolutions on how to reduce urban storms with expanding water space in mountain transition areas, while rebuilt more wetlands for providing urban ecological functions.

Erasmus Mundus Master Of Science In Ecohydrology - Presentation of PhDs' & Masters' works

ANTIBIOTIC EXPOSITION IN THE AQUATIC ECOSYSTEM OF SCHLESWIG-HOLSTEIN, NORTH OF GERMANY

Marie ARNAUD, University of Kiel, marie_et@hotmail.fr
Supervisors: PD Dr. Wolfgang SCHARENBERG; Dr. Uta ULRICH, University of Kiel

Key words : *Antibiotics, aquatic ecosystems, exposition risk, emergent contaminants, risk mapping*

Topic of this work : Study of the antibiotic usage patterns in order to assess the vulnerability of the aquatic ecosystem to antibiotic residues spatially and temporally.

Research question (or operational application) : What are the hot spots and hot moments of antibiotic residues contamination of the aquatic ecosystems in Schleswig-Holstein?

Originality of this work

Between 2000 and 2010, the world consumption of antibiotic increased by 36% reaching up to 200 000 tons per year (Wise 2002). Pharmacokinetic studies have determined that between 30% and 90 % of consumed antibiotics are excreted unchanged or as metabolite into the environment. Waste water treatment plants are not adapted to treat efficiently these compounds, most of them are released into waterbodies raising environmental concerns. Similar effects are caused by veterinarian antibiotics, which, incorporated in the manure, are spread on the fields and subsequently released into groundwater or surface water. Antibiotic residues have been increasingly detected in the environment over the past decade, mostly in surface waters, but also in groundwater, sediments, biota and even in drinking water world-wide (Kümmerer 2008). Despite a very low concentration with a range of µg/L, in many countries antibiotic residues exceed the Predicted No-Effect Concentration with subsequent implication for ecosystem health (Tamtam 2008, Kummerer 2008). Furthermore, the chronic exposure of antibiotic residues of the waterbodies (water and sediment) has been proved to have several detrimental effects, such as disruption of biogeochemical cycle (S,N,C), ecotoxicity to algae and microorganisms and promotion of resistant bacteria (Gullberg et al. 2011, WHO 2014) resulting in a decrease of antibiotics efficiency threatening human health. This raises the need of study about antibiotic residues in the aquatic ecosystem.

Germany is the biggest consumer of veterinary antibiotics in Europe (ESVAC 2014, ESVAC 2011). 85% of its total antibiotics consumption are used in veterinary medicine (Meyer, 2013). Therefore, it is crucial that Germany monitor effectively the veterinary antibiotics residues in waterbodies. However, there is a large number of antibiotic compounds of very heterogeneous fate and behavior following there physico-chemical properties and the local environmental conditions. In Germany, 250 different antibiotics have been reported (Kümmerer and Henninger, 2003). The observation and detection of antibiotic residues require a suitable point of time and place for monitoring. Pursuing ‘traditional’ methodology with full testing batteries for each compound would be very costly and might be inefficient. The development of tools for ranking these compounds according to their risk relevance for specific local environmental condition is hence necessary to ensure that the monitoring programme is spatially and temporally targeted for relevant compounds. In fact, prioritizing pharmaceutical compounds has been identified recently as a major need by a balanced group of scientists from government, industry and academia (Boxall et al., 2012; Cadwell et al. 2014).

The spatial heterogeneity of the antibiotic consumption practices and of the environmental factors requires local studies for compound prioritization and exposure scenarios to target effectively further

monitoring. In this purpose our study aims to develop a ranking procedure of veterinary product tailored for antibiotics, especially for the federal state of Schleswig-Holstein (SH) and to assess the exposition of the waterbodies of SH to the most at risk veterinary antibiotics. This work was realized in order to be useable for the establishment of a targeted monitoring program in aquatic ecosystem of Schleswig-Holstein.

Hence the study was divided into three parts. The first part reveal the local practice of veterinary antibiotics usage, the second part was a prioritization of the compounds and the last part the exposition and risk associated with the most at risk antibiotic residues in the aquatic ecosystem of SH.

Data and / or method

The local practices of veterinary antibiotic usage were determined by a mixed approach combining interviews and literature reviews. The quantitative approach in form of a web based self-administered questionnaire to veterinarians and a qualitative approach in form of in depth semi-structured interviews of key informants have been applied. The results were then completed and verified by epidemiologic studies. The triangulation of the methods facilitates the validation of the data through cross verification and capture a holistic, and contextual portrayal of the practices of antibiotic usage in Schleswig-Holstein.

The prioritization scheme was developed into four phases. Phase 1 was an initial broad screen limiting the antibiotic risk assessment only to the antibiotics with relevant usage for a risk. Phase 2 was to identify antibiotics considered to have the greatest potential to impact the environment. For these compounds, a hazard assessment was conducted (phase 3) classifying the compounds as very high, high, medium or low hazard on the basis of their aquatic and terrestrial toxicity based on Boxall (2003) study and Human toxicity profile based on Capleton (2006) study. Phase 4 was the ranking of the compounds following the combination of their potential to reach the environment and intrinsic hazard.

The exposure and risk assessment was realised for the most used compounds using the data collected in the previous part of our work. The exposition of antibiotics to aquatic ecosystem was realised following the VICH (EMEA, 2012) methodology and its adaptation by Menz et al. 2015.

Main results – expected results

1) Local practices of veterinary antibiotics usages

The antibiotic usage of Schleswig-Holstein isn't similar to others federal states since the herd are mainly composed of pigs and cattles. Within Schleswig-Holstein, hot spot of antibiotic usage can be found following the density of animals and type of farming. Some antibiotics, such as Amoxicillin, are intensively used comparing to others. For some compounds, the antibiotics usage follows seasonal patterns marked with hot moments of consumption.

2) Prioritisation scheme – expected results

List of the compounds the most at risk to take into consideration during monitoring

3) Exposition assessment and risk –expected results

Determination of the environmental concentration of the antibiotics mostly applied. Map of the vulnerability of the waterbodies following the compounds and the season in Schleswig-Holstein.

Discussion

This study would be the first spatial and temporal risk assessment in Germany of the veterinary antibiotic residues. The development of the prioritization scheme tailored for antibiotics could be used in others regions in Germany, or others nations. Finally, the deep characterization and the interdisciplinary of this work would provide accurate information to monitor the antibiotics residues in SH and find adapted local solutions.

APPLICATION OF PROBFLO TO THE MARA RIVER BASIN: AN INNOVATIVE METHOD TO DETERMINE ENVIRONMENTAL FLOWS

Kelly Fouchy1, John Conallin1, Gordon O'Brien2, Michael McClain1
1 UNESCO-IHE Institute for Water Education, Department of Water Science and Engineering, P.O. Box 3015, 2601DA Delft, The Netherlands
2 Institute of Natural Resources (NPC), P.O. Box 100 396, Scottsville, 3209, South Africa

Key words: environmental flows; Mara River Basin; PROBLO
(Subtopics 2.4;2.7)

Successful water management depends on the establishment of a balance between the use and protection of resources for the equitable benefit of all stakeholders. The Mara River and its tributaries (upper Nile Basin) represent an essential source of water for domestic needs, agriculture, mining, pastoralism and wildlife. To support an increasing water demand, there are short to medium term plans to modify the river system, including dam construction. Yet, this poses a threat to a range of social and ecological objectives in the Mara River Basin. Holistic environmental flow methodologies (EFMs) are transparent, adaptable and explicitly address socio-ecological trade-offs. Therefore this research aims at using PROBFLO, an innovative EMF, to make environmental flows recommendations in the basin. PROBFLO is an evidence-based, regional-scale risk assessment EFM that incorporates Bayesian Networks to evaluate the probabilistic relationships between flow-ecological-social variables of an ecosystem and how these may be influenced by flow alterations. A preliminary PROBFLO evaluation was undertaken using data available from literature, as well as local stakeholders and expert knowledge. Within the basin, ten risk regions were identified based on hydrology, hydraulics, land cover and land use. Simulations were run for each risk region, using high flow, low flow and drought hydrological data. The impact of different scenarios of hydrological alteration was assessed for six socio-ecological endpoints: basic human needs, ecological integrity, agriculture, livestock, ecotourism, and wetland. Based on these results, environmental flow recommendations will be made and compared with previous recommendations acquired following the Building Blocks Methodology. Results of this preliminary PROBFLO evaluation are expected to help define which surveys, in relation to hydrology, hydraulic habitat, geomorphology, water quality, riparian vegetation, fish, benthos and social attributes, are needed to further improve the model. This research was supported by the MaMaSe (Mau Mara Serengeti) Sustainable Water Initiative.

TYPHA DOMINGENSIS AND EICHHORNIA CRASSIPES AS REMEDIATORS OF HEAVY METALS IN A LATIN AMERICAN COASTAL LAGOON

Jacunem Lake, Brazil
naca_ns@hotmail.com

Abstract

Due to the growing rate of urbanization in many tropical coastal areas, there has been an increasing concern in relation to the impact of anthropogenic activities on coastal lakes. One of the southeastern tropical coastal Brazilian lakes, Jacunem, which lies in the central-eastern part of the Espirito Santo state, suffers from high ecosystem pressure mainly due to urbanization and industry. The purpose of this study was to verify the presence of heavy metals in sediment, water and plants of Jacunem lake and the ability of local floating macrophytes for phytoremediation processes, in order to define an ecohydrological strategy for water quality restoration in this lagoon.

The general objective of this work was to conduct an environmental assessment of heavy metals pollution of the Jacunem coastal lake, Serra, ES, Brazil, comparing the spatial distribution of each heavy metal in water, sediment and different organs of *Typha domingensis* and *Eichhornia crassipes*.

At this moment, metals in sediment, water and plants are being quantified by inductively coupled plasma-mass spectrometry (ICP-MS), with samples preparation using EPA methods 3051A and 3052 in within the environmental geochemistry laboratory of the Federal University of Espirito Santo. The upcoming results are expected to show significant differences in spatial distribution of heavy metal concentrations between different sampling points and within different matrices. Likewise, different metal concentrations in different organs of each specie and between species are expected.

These results will help to understand the role of each macrophyte specie in metals distribution and define an ecohydrological approach to reduce metal concentrations improving the water quality of Jacunem lake.

COMPARISON OF METHODS IDENTIFYING CRITICAL PHOSPHORUS SOURCE AREAS AND IN-STREAM PHOSPHORUS LOADS DURING A THREE MONTH PERIOD OF THE KALBACH, GERMANY

Nicolai Brekenfeld, Masters student of Erasmus Mundus Master of Science in Ecohydrology, e-mail: stu123007@mail.uni-kiel.de

Topic of this work

The adverse effects of high phosphorus concentrations in the aquatic environment have been recognized in the last decades and measures to reduce point and non-point sources have been implemented. After the reduction of major point sources, the focus lies now on identifying and reducing non-point sources. However, the identification of non-point phosphorus sources has been difficult and has been mainly based on several indirect methods such as export coefficients, soil loss calculations and farm based nutrient balances. But those methods might be misleading especially in lowland catchments with many small hills and depressions.

Research question

The objective of this study was to compare methods, which identify areas with a high risk of phosphorus loss and direct measurements of the phosphorus load in a small catchment (1000 ha) in northern Germany. The main channel and its tributaries were sampled at 16 sampling points on a weekly basis for a period of three month. In addition, agricultural fields close to the stream were classified based on their risk to act as a phosphorus source, export coefficients were applied to the subcatchments and previous studies incorporating farm based nutrient balances were used for the comparison.

Expected Results

Current results show that the two, small sewage treatment plants located in the catchment contribute a higher percentage to the total phosphorus load than it was previously expected. The stream reaches with the highest increase of the phosphorus load during high or medium and low discharge conditions are located in grassland dominated areas and areas, where erosion from agricultural fields is reduced due to riparian zones, respectively. Those results stress the importance of those sewage treatment plants and other factors, such as organic soils.

HYDROLOGICAL INFRASTRUCTURES AND WATER RETENTION CAPACITY OF SOILS IN A TERRACED LANDSCAPE, PONTA DELGADA-MADEIRA, PORTUGAL.

Valeria Fárez Román. EMMC in Ecohydrology - University of Kiel, Germany.
claudiafarez@gmail.com

Key words

Terraces, levadas, soil-water retention capacity, infiltration capacity, Ponta Delgada-Madeira. [1.1; 4.6]

Topic of this work

The Portuguese Island of Madeira is located between 32°45'N and 17° W in the Atlantic Ocean, 600 km from the African coast. The topography of the island is characterized by its roughness, having altitudes higher than 500 m.a.s.l. in about 90% of its area and an average terrain´s inclination of 56%. These features have been the driving force for the farmers to develop structures that could facilitate the agricultural activities. Nowadays, the North of the island´s agricultural landscape is characterized by terrace constructions which present a highly remarkable stability and by irrigation channel systems, known as "*Levadas*", which were built to secure agricultural production during dry periods. Within the terrace system, three types of structures can be differentiated exhibiting different wall configurations and construction materials. It is unknown the reason why certain structures are present in specific areas. Therefore, many factors could have been possibly taken into consideration when establishing the terrace systems that also contributed to its stability. Terraces have an ecological importance regarding to the prevention of soil erosion, the hydrology modification and the creation and change of microclimates (Field 1996). The construction of cropping surfaces with a slope less than the normal of the used site, reduces the velocity of runoff, allows a higher water infiltration and can create a storage volume where slower flowing water facilitates sediment and nutrient settling (Shao et al. 2013). Therefore terraces play an important role on slowing down the transfer of water and nutrients from the atmosphere to the soil and later on, to the sea.

Research objectives and methodology

The principal objective of the present research is to study five factors that could explain the different architectural structure of the three types of terraces in the area of Ponta Delgada, this factors are: soil formations, geological formations, slope, infiltration capacity and water retention capacity of terrace soils. As a component that is strongly associated with the terraces, the secondary objective is to study the levadas system determining its construction materials, distribution and discharge capacity.

For achieving these purposes, the methodology includes the analysis of soil and geological formation maps; the evaluation of the differences in slope using a Digital Elevation Model, within a geographical information system (ArcGIS); field measurements of infiltration capacity using the double ring infiltration method; and soil sampling in the upper terrace layer for analyzing the water retention capacity of the soils in the three studied locations. The analyzed types of terraces are

referred as type A: terraces with stone walls and three differentiated layers, the deep layer containing large
stones, intermediate layer with smaller stones and a superficial layer filled with soil. Type B: terraces also with stone walls and two layers, a deep layer with stones in different sizes and a superficial one presenting a thick soil layer. Finally the type C: terraces build up only with soil and which use to exhibit a frontal cover layer of grass, constituting the terrace wall.

Regarding to the study of the levadas the approach has included its mapping, the description of materials and the calculation of their maximum and average discharge capacity.

Preliminary or Expected results

Hitherto, the obtained results regarding to the soil and geological maps, show no difference between the formations in the three analyzed points. In relation to the water infiltration capacity, in the type A terrace the values are much higher (1146 mm h^{-1}) than in types B (180 mm h^{-1}) and C (397 mm h^{-1}), which could be explained by the differences in the deep soil layers, however it will have to be also correlated with the results from the soil-water retention capacity analysis, which are in development. For the study of the levadas, a map including the main and secondary channels has been developed. The calculations for the length of the channels gave a total of 8584.86 metros and currently the values for the discharge capacity are being calculated.

This research contributes to have a better understanding of the possible reasons for different terrace structures within a system that is highly resistant to erosive processes, this characteristic has enabled its conservation over the years. And, to determine the principal features of the levadas which have not been studied in the area of Ponta Delgada. Both of them, the terraces and levadas systems, constitute remarkable components of the agricultural history of Madeira Island.

References:

Field, Chris. 1996. *A Reconnaissance of Southern Andean Agricultural Terracing*. Edited by National Research Council. Washington, D.C.: Clearinghouse, Springfield Va.

Shao, H, C Baffaut, J E Gao, N O Nelson, K A Janssen, G M Pierzynski, and P L Barnes. 2013. "Development and Application of Algorithms for Simulating Terraces within SWAT." *Transactions of the ASABE* 56 (5): 1715–30. doi:10.13031/trans.56.10047.

CATCHMENT INFLUENCES ON THE HYDROLOGICAL FLOWS TO LAKE TERRA ALTA (LINHARES, ES, BRAZIL) AND ECOHYDROLOGY PERSPECTIVES

Mónica Gago González
Federal University of Espirito Santo (UFES), University of Algarve (UAlg);
e-mail: monica.gago.gonzalez@gmail.com

Key words: Hydrological flows, Ecohydrology, Catchments moprhology, Catchments hydrology. Integrated Lake Basin Management.

Lake Terra Alta (LTA) (A= 3.9 km^2; Z_{max}= 22.1.m) is a tropical natural lake located in the State of Espírito Santo (Brazil) being one of the 90 lakes which form the Lake District of Lower Doce Rover Valley (LDRV). LTA catchment area is 144.7 km^2 and is composed by 8 subbasins and 7 tributaries streams. Its predominant land use is pasturage and smaller dimension cropping and *Eucalyptus* forestry, with no urban area or industrial activities. The lake host an intensive fish farming facility on floating cages with *Tilapia*. Catchments morphometry and land uses have implications on the catchments hydromorphological processes, thus influencing hydrological flows to downstream lakes. Therefore, hydrological knowledge is necessary to subsidize basin management plans. LTA is under pressure of direct water withdraw for irrigation, as well as water withdraws from the tributary rivers and fluvial damming. Nutrient inputs from catchment natural loads and anthropogenic activities (i.e., agriculture, livestock, forestry), as well as from fish farming also stress lake trophic state. Those pressures may compromise lake ecosystem services that are provided by water quantity and quality. In this regard, an echohydrological approach provide a more concise support for Integrated Lake Basin Management (ILBM), considering the relationships of lake catchment, stakeholders and governance systems.

The main goal of this study is to evaluate the hydrological flows to LTA under an ecohydrological approach, integrating catchment morphometry, hydrography, hydrology, and land uses. Basically the study is based on a georeferenced database, river discharge measurements and modeling, and hydrochemistry of tributary streams and lake water and retention time. Loads of nutrients will be estimated and analyzed through multivariate statistical analysis (i.e., PCA) in relation to catchments features.

Is expected that this study will provide accurate information in order to establish a decision tree for the most suitable ecohydrology responses for inflow nutrient abatement and improve freshwater inputs to lake ecosystem. In turn, it is expected to ensure ecosystem services provided by LTA.

ASSESSING THE SUSTAINABILITY OF WATER RESOURCE USE IN THE TUCSON BASIN AND FEASIBLE OPTIONS TO INCREASE RESILIENCE

Kristin Kuhn, UNESCO-IHE, kuhn.kristin@posteo.net

Key words: water supply sustainability, resilient water supply, ecosystem services, water re-use, green infrastructure

Historically, the City of Tucson in the Sonoran desert of Southern Arizona has relied almost entirely on groundwater pumping for municipal and agricultural use. This dependence has depleted the aquifer and damaged the riparian corridor of the Santa Cruz River, which relied on shallow groundwater levels. Once the Central Arizona Project (CAP) arrived in 1993, the city reduced its dependence on groundwater by blending the imported Colorado River water into the municipal distribution system. However, even this new water supply will not be sufficient by 2040 to meet the continuing population growth. In addition, the future Colorado River supplies are uncertain due to drought and over-allocation.

This research project was designed to demonstrate the availability and use of alternative water resources to play a significant role in filling the future gap between demand and supplies. This research provides insight and understanding into the dynamics and sustainability of the water management system in Tucson for municipal and environmental needs. This research includes: (1) comments and observations on these issues from a diverse group of local water managers and stakeholders (obtained through participatory meetings and semi-structured interviews); (2) problem solving approaches and management strategies proposed to help balance the water budget; and (3) a critical analysis of current and future water resource uses, projects and policies (through review of literature, water management and planning reports, expert interviews). Increased use of innovative approaches are examined, such as rainwater harvesting, stormwater capture and individual grey-water systems, as well as the use of reclaimed water for indirect and direct potable re-use. Special emphasis was given to the inter-relations within the different water sources and their future potential to benefit the water balance and the enhancement of ecosystem services.

This research concludes that integrative management of water resources and better utilization of ecosystem services will help to ensure the sustainability of water resources and enhance the quality of life for the Tucson metropolitan area. This can best be accomplished by water management policies which recognize ecosystem services and support efficient utilization of all available water resources.

ANALYSIS OF GROUNDWATER DEPENDENT ECOSYSTEMS IN ARID REGIONS: CASE STUDY IN WADI WATIR, SINAI, EGYPT

Karim M. Morsy[1]

[1] EMMC in Ecohydrology, UNESCO-IHE, ***E-mail: kareemmorsy@ymail.com***

Keywords: Groundwater recharge, GDEs, ecosystem, Hydrus, remote sensing and stakeholder participation.

Topic of this work

Groundwater recharge and groundwater dependent ecosystems are subject of question nowadays, especially if the ecosystem protection can be exaggerated.

Research question (or operational application)

Is the task of ecosystem management to reach the original state or should the focus be to balance human interest with the health of system? This study focuses on the current knowledge of the groundwater recharge modeling using Hydrus package and GIS models comprising the role of dams in increasing the groundwater recharge and soil water content. It examines the groundwater dependent ecosystem health with and without dam and adapts options for better management in arid regions.

Originality of this work

This research is conducted in response to the growing concern about potentially unsustainable groundwater level declines, local subsidence and degraded groundwater dependent ecosystem (GDEs) in many basins and common recognition that further action is required to promote and achieve groundwater sustainability throughout Wadi Watir as arid region. It aims at estimating the recharge rates based on the current knowledge for two different scenarios using Hydrus and GIS programs: (a) the first scenario is to simulate the groundwater recharge process under the normal conditions, and (b) the second scenario is to simulate the groundwater recharge process taking into account the effect of dam structures (e.g., water harvesting structures) located at the outlets of the main sub-catchments.

Data and / or method

The study includes an ecosystem assessment to examine the ways links are made between ecological systems, structures and water sustainability. Understanding interconnection among the ecosystem and the human benefits is fundamental for the development of effective assessment, methodology and policy to achieve sustainability of water resources and better ecosystem health and services. The need to assess the effects of variability in geology, climate, biota, ecosystem and human activities on water availability. As global concerns over water resources and the environment increase, the importance of considering groundwater and surface water as a single resource has become increasingly evident.

Main results

It is found that the output results of the first scenario (with dam) will give higher soil water content than the second scenario (without dam). Increasing the water content will increase the safe yield leading to better ecosystem health. Accordingly, these results will assist the decision makers to: (1)

estimate the water storage; (2) define the best methodologies and techniques to avoid water harvest; and (3) manage the land usage and requirements needed for a new urban projects.

Conclusion

This study allows the decision makers and investors to identify the safe yield extraction of the groundwater, and the possibility of having more agricultural areas and urbanization projects within the study area. Overall, the recommendations call for an immediate intervention to study scenario analysis and impacts are required to predict the recharge behavior in the future to get effective groundwater management and healthy ecosystem.

WATER RESOURCES IN LAKE TANA BASIN: STATISTICAL ANALYSIS OF RAINFALL AND STREAM FLOW TIME SERIES

Tibebe B. Tigabua[1,2]
Georg Hörmann[1] and Nicola Fohrer[1]
[1]University of Kiel, Department of Hydrology & Water Resources, 24118 Kiel, Germany,
[2]University of Gondar, School of Technology, Department of Water Resources & Environmental Engineering, Gondar, Ethiopia
Email to correspondent author: tibebghw@gmail.com

Key Words: Lake Tana, autocorrelation, cross correlation,, streamflow, rainfall, temperature

Abstract

The main focus of this research was to conduct statistical analysis of hydrological and meteorological time series in Lake Tana Basin, Ethiopia. Use of R packages, statistical tests such as Mann-Kendal (MK) monotonic trend test, lag auto and cross correlations tests, Pennman Monthieth & Hargreve PET computation methods and GIS applications were the major approaches. Long term daily rainfall, temperature, lake level and river discharge data were used. Based on this analysis, the mean annual rainfalls of the several stations are decreasing from decade to decade. For instance, annual rainfall of Bahirdar station is dropping with a slope of 6.6. On the other hand, the annual mean minimum temperature is showing an increasing trend. Even though there are changes in the annual mean values of rainfall, streamflows, lake level and temperature data, the MK monotonic trend test employed for this research indicated that there is no significant trend in most of the data series. Analyses of streamflows indicated that decadal mean flows of Abbay and Gilgel Abbay are decreasing where as decadal mean flows of Gumera, Megech and Ribb are increasing. The decadal mean of Abbay was 142.54 m^3/s during 1990s and dropped to 131.20 m^3/s for 2000s.Additionally, Abbay flow is showing high year to year variability that increases from 34% (case of 1990s) to 40% (case of 2000s). The decadal annual mean of lake water level has also shown a decreasing trend from 1990s to 2000s. It showed a negative difference of 0.31 m and 0.29 m between 1980s-1990s and 1990s-2000s respectively.

Lag time autocorrelation and cross correlation tests were also carried out for rainfall, temperature and discharge time series. The autocorrelation functions (acfs) were significantly different from zero indicating that the sample data are nonrandom. The maximum acf values are at time lag 1 and decreasing linearly as the time lag increases, indicating that data come from an underlying autoregressive model (AM) with moderate to strong positive acf. When we consider the cross-corelation functions (ccf) between rainfall and streamflow of the complete data set, good correlation coefficients are observed at negative time lags. There is a time shift of 15 to 30 days to get highest ccf values indicating that streamflows respond later than the peak rainfall occurrence.

In general this research showed that there is considerable variation of rainfall, streamflow, lake level and maximum and minimum temperatures both on time and space dimensions.

ANALYSIS OF WATER QUALITY IN A TRANSECTION OF THE VERESCHYTSYA RIVER IN RELATION TO LANDSCAPE AND RIVER CHARACTERISTICS

Nikolenko Olha Christian-Albrechts

University of Kiel, Hermann-Rodewald-Str.4 24118, Kiel, Germany nikolenko_olha@ukr.net Key words (small rivers, hydrological regime, heavy metals, nutrients, ecohydrological approach)

In recent years the studies of processes occurring in the ecosystems of small rivers attract increasing scientific interest as is becomes widely recognized that their multiple impacts on local communities and natural environments in many cases might extend far beyond the boundaries of their watersheds (Marushevsky, G., 2005). In particular, much effort is devoted to understand the influence of the small rivers on the higher-order streams as it purportedly plays significant (yet underexplored) role in dynamics of environmental parameters (pollution, species diversity, hydrology) of the basins of large rivers which depend on smaller tributaries as their water source. However, environmental impact of small rivers can scale up to large areas in different ways, and this study explores the case of specific managerial concern: how the hydrological regime and contamination of the small rivers influence water quality in the water intakes located in their basins and thus determine quality of environmental services provided to abundant urban populations.

It explores these issues on the showcase of the Vereschytsya river which is the left tributary of the Dniester and flows in the Western Ukraine. The Vereschytsya river basin entrenches deeply into the hills of the Baltic Sea drainage area and its frontiers along 10 km are the boundaries of the Main European Watershed. With the length of 92 km, the basin of this river contains six water intakes which provide the adjacent settlements and the million plus city of Lviv with the potable water. According to the recent studies the increased concentrations of nutrients and heavy metals have been detected in water of water intakes in the Vereschytsya river basin (Kharkevich, V., 2013). The deterioration of the surface water quality may be one of the reasons which caused this situation. Due to intensive water exchange between the surface and ground waters because of the high fracturing of the water-bearing rocks caused by two tectonic faults crossing the area, the polluted surface waters might easily percolate into the ground water horizons thus exacerbating the situation further.

Degradation of the Vereschytsya river water quality endangers not only potable water supply, but also other environmental services. For instance, while the water resources of the Vereschytsya river are actively exploited for fishery purposes, in the last decade the decrease in the biodiversity of fish species has been observed due to the pollution of the surface waters, their shallowing and draining of marshes (Grekh V., 2009).

As a result, the hydrochemical and hydrobiological situation in the basin of the Vereschytsya river demands “dual regulation” for improvement of the conditions of this aquatic ecosystems, which can be accomplished by combination of the hydrological and ecological insights intertwined in the optimal ecohydrological managerial approach (Zalewski, M., 2002).

This study attempts to provide basis for managerial decision-making in this case as it explores the abiotic factors that influence water quality, focusing on the studies of the hydrological regime of the Vereschytsya river. It estimates and analyzes the seasonal dynamics of river flow and factors that affect it (surface runoff, infiltration, natural ground water recharge ect.), thus aiming to define the relationships between the hydrological parameters and the intensity of polluted substances accumulation in the surface waters, soils and bottom sediments of the river basin. Comprising analysis of hydrology, soil types and land use along the Vereschytsya river continuum, it identifies the

characteristics of hydrochemical processes that occur in the river basin and the key factors that have an influence on them processes at different locations within the watershed (Krysanova, V., Arnold, J., 2008).

Therefore, the aim of this research is to analyze the hydrological and hydrogeochemical regime of the natural waters in the Vereschytsya river basin and estimate the influence of the natural and technogenic factors on the change of surface water composition in order to optimize the monitoring of water ecosystems and develop preventive measures against water pollution.

In order to characterize the dynamic of hydrochemical and hydrological regimes of the Vereschytsya river and define the ways for the improvement of its ecological conditions the accomplishing of the following research tasks is planned:

1) to estimate the water balance of the Vereschytsya river basin by means of modeling approach considering the spatial diversity of basin characteristics: land use, soil types, meteorological conditions and features of river network;

2) to analyze the distribution of heavy metals and nutrients in the surface waters, soils and bottom sediments in the basin of the Vereschytsya river;

3) to examine the relationships between the concentration of pollutants in the surface waters, soils and bottom sediments and hydrological regime of the Vereschytsya river and the soil types in this river basin on the base of the statistical analysis;

4) to develop measures which will contribute to the improvement of the environmental conditions of the Vereschytsya river ecosystem.

In order to accomplish these tasks, this research exploits the data about the meteorological and hydrological conditions for the period 2003-2013 years and the results of the chemical analyses of surface waters, soil and bottom sediments for the period 2012-2013 in the basin of the Vereschytsya river.

It is expected that this study will reveal the regularities of the heavy metals and nutrients distribution in the surface water, soils and bottom sediments of the Vereschytsya river basin. Furthermore, it is expected that the factors that have most significant influence on their distribution will be identified, which will help to detect the ways of pollutants inflow and the places of its accumulation in the basin.

The results of this research will help to shape the ecohydrological approach to be used for the improvement of the conditions of the Vereschytsya river basin and increase of its absorbing capacity (Zalewski, M., 2012). Moreover, the outcomes of this study might be applied for optimization of the monitoring system of the Dniester river, in particular, the control of the conditions of small rivers. The continuous monitoring of the hydrological, hydrochemical and hydrobiological parameters of the small rivers will give the opportunity to react timely on the changes that occur along the river continuum in order to preserve and restore aquatic ecosystems (Arthington, A., Bunn, S.,et al., 2006).

Reference list:

Arthington, A., Bunn, S., Poff, N., et al., 2006. The challenge of providing environmental flow rules to sustain river ecosystems. Ecological Applications, 16(4), 1311-1318.

Grekh, V., 2009. Fish resources of the Vereschytsya river: usage, renewal and protection. Visnyk Lvivskoho Universytetu. Seriya Geografichna 37, 164-176.

Kharkevich, V., 2013. Проблема охорони водних ресурсів Західного регіону України. [Problems with protection of water resources in Western region of Ukraine]. Environment people law journal 19-20, 77-93.

Krysanova, V., Arnold, J., 2008. Advances in ecohydrological modeling with SWAT – a review. Journal of Hydrological Science 53:5, 939-947.

Marushevsky, G., 2005. Участь громадськості у збереженні малих річок України: Дубровський, Ю., Використання малих річок і проблеми збереження їхніх ресурсів. [Public Participation in the Conservation of Small Rivers: A Training Manual: Dubrovsky, U., Exploitation of the small rivers and its preservation], Wetlands International Black Sea Programme, Kyiv, pp. 18–29.

Zalewski, M., 2012. Ecohydrology – process oriented thinking for sustainability of river basin. Ecohydrology&Hydrobiology 12, 89-92.

Zalewski, M., 2002. Ecohydrology – the use of ecological and hydrological processes for sustainable management of water resources, hydrological Science Journal, 47:5, 823-832.

Achieving of the equilibrium between aquatic ecosystem services and human usage of water related resources is constrained by ecological and social factors which can be addressed using adaptive spatial planning based on natural processes.

Fundamental and applied researches to support this equilibrium are being developed in the disciplines of EcoHydrology, EcoHydraulics, Ecological Engineering, and Social-Ecology.

This conference was aimed at bringing together leading researchers and practitioners from these disciplines to present the latest advances in knowledge and practice and to promote increased dialog and collaboration between these disciplines.