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Managing Drought and Water Scarcity in Vulnerable Environments

Proceedings of the 10th European Seminar on the Geography of Water

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Editor Antti Roose

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Antti Roose
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Water conflicts in Spain and Andalusia

Water conflicts and management are without question among the central issues facing the international and European community if we are to meet targets for a healthier, more stable, and sustainable world. Sustainability involves environmental integrity, economic efficiency and equity for present and future generations [5]. The sustainability concept changes radically the traditional thinking and perspectives on water environment as well. Since the Industrial Revolution, most of Europe's rivers have been treated more like a convenient way of transporting waste to the sea, harming human health, destroying the biodiversity of thousands of kilometres of waterways, and polluting coastal waters. If waters are polluted, we can clean up a river. But if there is water scarcity, no water, it is far more difficult. Water pollution and water scarcity are listed as priority issues among the environmental problems in the Mediterranean [3].

In connection with the curricula and studies of the European seminar on the geography of water in Andalusia in 2006, let me list a few of the problems concerning water environments in Spain. Spain's national environmental profile says it quite straightforwardly: fast economic development has come with increasing urbanisation and intensive use of resources. At the same time, environmental management has been strengthened, leading to improvements in water treatment and water use [3]. Spain also faces several specific problems linked to its climatic and geographic characteristics: fires, droughts, erosion and flooding. Regarding human impact, the Mediterranean coast hosts a myriad of business, economic, social and human activities, including steadily growing mass tourism, which all constitute important causes for the degradation in the coastal zone, damaging inland waters as well as affecting the marine ecosystem. In this respect, the main issues of concern are sewage and urban run-off. Eutrophication, wetland and salt-marsh destruction is also very common [3]. Total water abstraction in Spain is very high given the available resources, with a growth of 3.4 % between 1997 and 2002. Economic development and urban expansion, together with the use of water for agricultural purposes (about 76 % of total water abstraction), in combination with the Mediterranean climate of a large part of the country, exert strong pressures on water resources. We know already that Spain is seeking to abandon the current centralised, often large-scale management practices based on supply measures such as transferring water resources between hydrological basins [4].

Drought management

Drought, being a normal recurrent feature of every climate, combined with water scarcity, has dramatic effects on the Spanish economy and the environment, on the Spanish people themselves and the population's well being. Drought events affect rain-fed agriculture as well as water supplies for irrigation and domestic water, and delay economic development in addition to adverse environmental and social impacts. Drought events in Spain have been frequent after 1970. Spanish communities tend to react to a drought by responding to immediate needs and by providing what are often costly remedies attempting to balance competing interests [1].

Historically, the urban, cultural, and agricultural development in Spain has demonstrated a profound knowledge of adaptation strategies to drought, water scarcity, and precipitation variability. It is uncertain how efficient the institutions for incorporating drought preparedness are in the cases when drought did not cause major negative impacts due to institutional planning strategies. Thus, the Spanish institutions and organisations have the instruments, legislation, and structures to manage drought [2]. Nevertheless, there is room for improvement on the risk analysis within the contingency plans of the hydrological basins. Drought management should incorporate drought forecasting, risk and impact assessment, and profound and comprehensive drought contingency planning. In respect to the economic effects of drought management, it is asserted that for every euro invested a return of two or more euros may be expected. What is common approach, implications of sustainability in water resources management in cases of scarcity and drought should be decided at catchment scale. Future adaptation options of the basin institutional framework to the requirements of planning is based on risks analysis and a strategic approach. In addition, climate change will aggravate the water problem. Drought does extend over long periods and large areas; further North, drylands are growing. The link is also there with biodiversity. It is also vital that we look at drought and water conflicts as local issues involving the particular circumstances of local people. In the summer of 2006, we as participants of the European seminar were taught and saw the choices facing and solutions taken in Andalusia regarding drought. I hope the experience and innovative, research-based approach on drought management of the Andalusian community will be an inspiration.

10th European seminar on the geography of water and its outputs

This publication is the result of the 10th European Seminar on the Geography of Water under the title of the Socrates Erasmus Integrated Programme «Water Resources and Conflicts in Southern European Ecoregions – Pontic Province and Mediterranea», held in Seville on June 26 – July 6, 2006.This publication in the series *Publicationes Instituti Geographici Universitatis Tartuensis 101* aims to present regional approaches of water conflicts and management in Andalusia, Spain, as well as case studies on water environment from other parts of Europe, but also from Africa and South America. The authors for this publication were invited on the basis of their input in the seminars on the geography of water, as well on geographical and topical criteria to focus on the hydrological, environmental and social analysis of drought, water scarcity and pollution, and its management. I am very glad that many of participants of the residential seminars in Seville, 2006, as well as in Tartu, 2005 accepted this challenge, which required extra work to upgrade posters to full-scale research articles.

Since 2005 the Socrates Erasmus project on the geography of water is coordinated by the University of Tartu, as a continuation of the leadership of the Johannes Gutenberg University Mainz. The high point of the project was the residential seminar in Seville hosted by the University of Seville, on June 26–July 6, 2006. The objectives of the project were to develop post-graduate study programmes on EU Water Framework Directive approaches in the Southern-Central European context and implement know-how transfer on water management graduate courses between participating universities as follows: University of Tartu, Estonia; University of Seville, Spain; Johannes Gutenberg University Mainz, Germany; Charles University in Prague, the Czech Republic; University of Pecs, Hungary; University of Udine, University of Padua, University of Cagliari, Italy; University Jean Monnet, Saint Etienne, France; Sofia University St. Kliment Ohridski, Bulgaria; Linköping University, Sweden. Flexible new adaptation strategies were employed for successful implementation of the Water Framework Directive. This took into account results of the case studies assessing the specific vulnerability of water systems considering different socio-economic, municipal, industrial and agricultural, technological and engineering aspects of water use in different European countries. On the research level, the project activates a platform of scientific exchange between water experts of the participating European universities. Similarly to the scope of the 2006 residential seminar, the post-graduate research priorities have been based on research results to reduce industrial, agricultural, drought and flood impacts and to strengthen the delivery of corresponding water management tools and services through scientific cooperation, workshops and joint fieldwork. During the seminar in Seville, the field was divided into four workgroups: drought management; river restoration; agricultural uses, and challenge of application of Water Framework Directive. Lectures, fieldworks and working group sessions allowed us to synthesize materials and to draft conclusions on specific problem area. The participants of the seminar conducted an intensive brainstorming in workgroups on acute water problems and their implications. The seminar included the participation of 13 professors, lecturers and 25 postgraduate students representing all 11 participating universities (see list at page 208).

The academic output of the participants is published as this seminar publication. The articles are organized with an Andalusian introductory section that outlines selected issues of the water environment and management in Sevilla and its surroundings, sites visited during the seminar. Five papers cover a regional range of water approaches, *Empirical and practical considerations of drought management*, by Leandro del Moral, *Urban growth on riverbanks of Guadalquivir River*, by Antonio Garcia Garcia, *Coastal ecosystems and river restoration of the Guadiamar River*, by Baena Escudero and Guerrero Amador. Leandro del Moral stresses in his keynote article that there is a paradigm and culture change in Spain, similar to the European approach to water management, from centralist infrastructure dependency towards distributed, adaptive, integrated systems. However, the publication does not attempt to assess the state of the Mediterranean water environment exclusively and in particular. Instead, the book addresses specific issues which are of main concern for sustainable water management and its socio-economic implications in Andalusia, Spain and also in other participant countries. The Andalusian section is followed up by the country sections, research articles from France (1), Estonia (2), Czech Republic (3), Hungary (3), Italy (6), and Germany (1). These articles give an interesting international or national representation of the case studies for understanding and managing the water environment. Sections include research of participating professors and post-graduate students, whose findings on water quality or socio-economic impacts of water pollution were presented in a Seville seminar as lectures or posters. Research articles document the water surveys, analysis, modelling and experience on the application of water and drought management plans. Academic writers and postgraduate student have offered a number of extremely useful insights concerning water management and human impacts. A few articles were presented already in a seminar in Tartu in August 2005. Research presented in this book is rooted in real local problems. Three articles are based on field research and case studies outside Europe, PhD expeditions in Senegal, in Burkina Faso and in Brazil. The last paper presents a historical overview of the tourism use of the River Rhein in Germany.

As a co-ordinator of the Socrates Erasmus Intensive Programme I am totally delighted by the results of 10th European Seminar on the Geography of Water. On behalf of the University of Tartu and the participating universities I would like to thank all professors, lecturers and participants for coming and joining this course in Seville. We must build further our academic partnerships on the pressing water environment issues of our time. That is our strategic goal. To be effective we need to not only develop on a single curriculum on the geography of water for this project, but also to cooperate fully on water research, integrating knowledge and know-how from our different countries. We all really invested in this pan-European co-operation in the field of the geography of waters over the decade of seminars held in different European countries. This is a tradition to be continued.

Finally, we all thank the University of Seville for an excellent programme and study environment at the seminar in Seville, in June and July, 2006. We were very delighted with such magnificent work done by Dr. Belen Pedregal Mateos and her team to prepare this seminar, curriculum, courses, lectures, tutorials, accommodation, and logistics - all in all, for the very kind and touching Andalusian hospitality. Hereby we thank all the Seville team for their input to find time, people and resources among other tasks.

We gratefully acknowledge the universities, participants and authors for their valuable input in this book. Special thanks are due to Eva Liivak for project administration, Egdar Sepp for seminar photos, Priit Kivisoo for the design layout of this book, Ilmar Part and Alexander Harding for language editing and the Tartu University Press for the publishing this book. We thank all technical support and stakeholders who have contributed to the success of this book. Finally, we are grateful to the European Commission for the Socrates Erasmus grant support.

We wish the reader discoveries, inspiration and new endeavours.

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Managing drought and water scarcity in Spain. Fundamental water policy debates

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Abstract

Economic, social and cultural changes, the high level of deterioration of the aquatic environment and a rise in inter-regional conflicts can be associated with the decline of the prevalent water policy in Spain. Criticism of this situation has spread widely across society, undermining the logic of the old paradigm, but without coming up with an alternative model to date. Underlying this apparent stalemate, however, is a powerful dynamism of ideas and socio-political processes. Fundamental topics under discussion include changes in the social perception of the water environment, the evaluation and distribution of the cost of managing water as a resource, the repercussions of water politics on socio-economic and spatial development and the reform of the institutional water management framework. This paper analyses these debates, paying particular attention to the discursive aspects, that is, the ensemble of ideas, concepts and categorizations through which meaning is given to physical and social realities.

Keywords: Hydraulic paradigm, water scarcity, drought, Spain

Hydraulic politics as a central issue in the construction of the Spanish modern State

For over a century, one particular water management policy has prevailed in Spain, namely the *hydraulic paradigm* or the *hydraulic mission*, which has been well described elsewhere in an extensive bibliography [2,8,28]. The central axiom of this late 19th century paradigm consisted of the need to provide an adequate water supply for all those social agents who were prepared to use it for the development and modernization of the country.

This idea entailed a project for the geographical transformation of the country: the *regeneration*, the *revival* (*la regeneración*) of an adverse landscape characterized by aridity and barrenness and the resulting under-development and lack of growth. A landscape able to respond favorably to tenacious human involvement based on sound geographical knowledge, technique and the collective will. Any hope that the private sector would be able to pool the needed resources to promote this project for physical, economic and moral regeneration had been ruled out over the previous decades.

Thus, end-of-century regerationists entrusted the governments to use tax money and lead the country in this grand-scale endeavor.

Joaquín Costa (1846–1911) became one of the main advocates and potent symbols of this broad social movement for modernization through Hydraulic Policy (*Política Hidráulica*), in which water engineering would be the substratum for fostering growth, permitting social reform and cultural emancipation.

The specific characteristics and different historical manifestations of the hydraulic paradigm throughout the 20th century in Spain have been addressed often both by Spanish authors [10,12,19,23,24] and by authors of other nationalities [6,31]. Neither the recent history of the country, nor its present geographical layout can be understood without taking into account the involvement and radical transformation of the water environment.

While other industrialized European countries, such as the United Kingdom, France and Belgium, were consolidating colonial expansion overseas at the end of the 19th century, Spanish society was in a state of shock at the loss of its last colonial possessions (Puerto Rico, Cuba and the Philippines), following a disastrous war against the United States in 1898. In the absence of an overseas colonial project as a means for modernization, Spanish elites advocating social and economic reform concentrated their efforts on a national program, involving a radical transformation of the country's geography [31].

This vision combined a decidedly political strategy, a call for a scientific-positivist understanding of the natural world, a scientific-technocratic engineering mission and a popular base, rooted in a traditional peasant rural culture. It united diverse social and political sectors (reformist, socialists, populists, industrialists and enlightened agricultural elites), while keeping the more radical left-wing forces (revolutionary socialists and anarchists) and the traditionalist conservative right at bay. This alliance of reformists, focused on reconstructing the country's hydraulic geography, served the twin purpose of uniting hitherto excluded political sectors into a powerful coalition, while addressing social conflicts by seeking to prevent radicalization [31].

Yet, in view of the limited prospects of private investment, the regenerationists regarded the State as the only body capable of generating the investment funds required to mobilize the country's water resources. They pushed through the necessary reforms in the face of strong and sustained opposition from the traditional oligarchies. At the same time, the support of part of the old elites could be secured via this reformist route, which did not threaten their fundamental rights as landowners and defended rural power against the rising tide of the urban-industrial elites and proletariat.

Furthermore, hydraulic politics, hailed as the top priority by the country, played an important role in the social legitimization of the State. The reformism advocated the *hydraulic regeneration*, whereby the State would take center stage to organize the necessary socio-spatial transformation. After the failed attempts to initiate reform during the first few decades of the 20th century, it would provide a substratum on which the later Falangist (Spanish fascist wing) ideology would thrive.

The regenerationist agenda, in fact, only materialized on a grand scale after the Civil War, during the Franco regime (1939–1975). Although coalitions of social agents, objectives and means

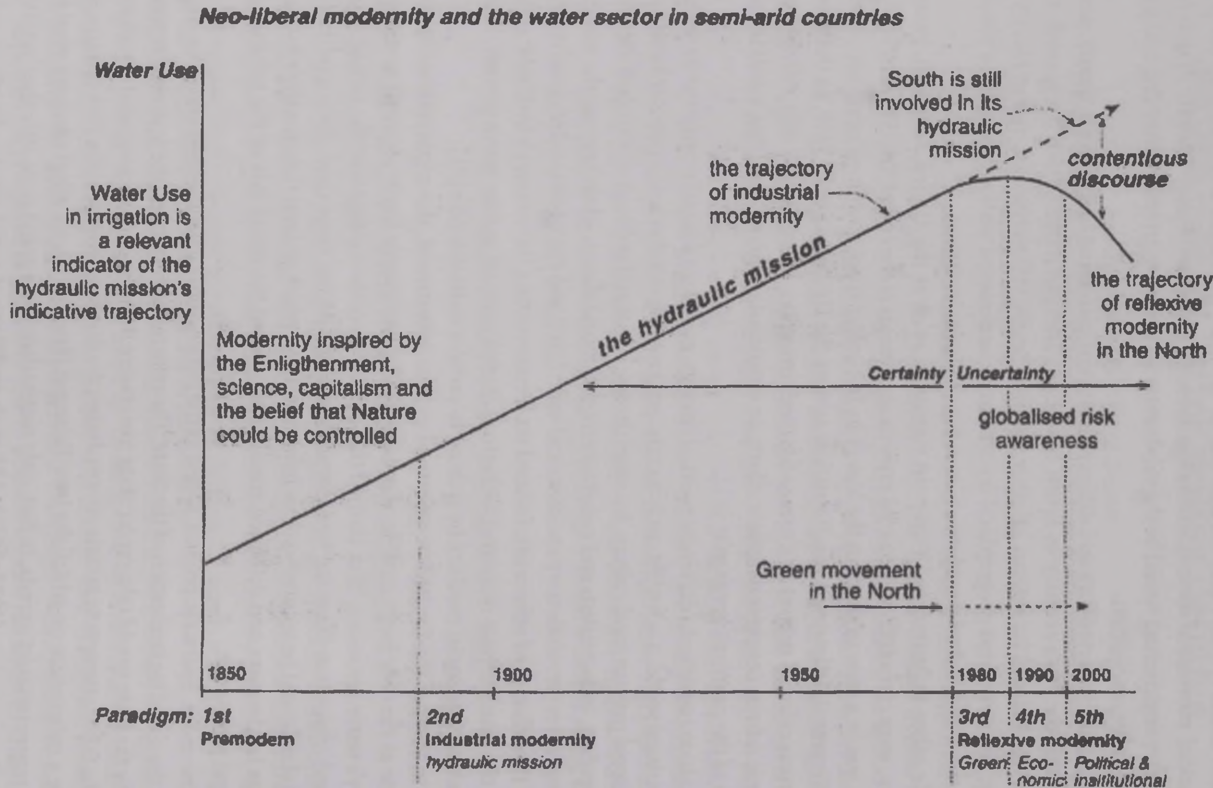

Figure 1: The five water management paradigms. Source: Allan, 2003

would change over time, the geographical basis for modernization would remain the constant guiding principle. The vision of modernization based on *hydraulic regenerationism* became the lynch pin of progress and development in Spain until the end of the Franco era.

This hydraulic regenerationism advocated by Joaquín Costa coincided with an *intellectual regenerationism*, symbolized by the movement of poets, writers and thinkers known as the Generation of 1898 (after the year of Spain's defeat in the Cuban War – 1898). This movement rediscovered, both aesthetically and sociologically, the underdeveloped regions of arid inland Spain (Castile), whose only prospect of future emancipation lay in embracing hydraulic politics. The 'hydraulic desire' of these arid lands became the leitmotiv of much of the Generation of '98 literature at the time (Unamuno, Azorín, Baroja, Macías Picabea and others).

Implementation and crisis of the traditional hydraulic paradigm

While the turn of the 19th century was characterized by the dynamic development and expansion of the discourse of hydraulic regenerationism, the 20th century was to be characterized by the slow and tortuous implementation of the geographical project proposed by the regenerationists. In spite of the 1902 and 1933 plans for hydraulic engineering works and the creation of river basin authorities (*Confederaciones Hidrográficas*) from 1926 onwards, the hydraulic project failed in its attempt to quell the outbreak of social unrest that eventually led to the Spanish Civil War (1936–1939). Following the Civil War, hydraulic politics in the Franco regime became an instrument of control, national integration and autarchic development. Although the rhetoric of the original social objectives was maintained, the emphasis gradually shifted towards the discourse of reconstruction and 'national' development [22,31].

In 1959 there was a break with the largely inward-looking development model followed in the forties and fifties. Preparations for European Community membership, the opening up of the economy and the progressive incorporation of Spain in the international community required a renewed intensification of the country's resources to meet the demands of fiercer international competition. Its competitive advantages in the production of fruit and vegetables and the booming tourist industry on the Mediterranean coast led to an increase in the demand for water in the driest areas of the country. In the seventies, work began — still in a context of social consensus on the water policy model to be followed – on the first major water transfer between river basins, from the River Tajo basin to the River Segura basin.

Following the death of Franco (1975) and the restoration of democracy (1978 Constitution), the Spanish democracy had to rise to the challenge of meeting the demands placed on it by rapid growth in a context of increasing integration in Europe and economic globalization. At the end of the 1980s, discussion began on new water management policies designed to meet the growing demand for water as a result of rapid economic growth, primarily by means of massive water transfers between river basins. This was the main thrust of the draft National Hydrological Plan (NHP) presented in 1993. Significantly, the introduction to the Plan, advocating what it called the National Integrated Water Balance System (SIEHNA), ended by stating in the truest hydraulic regenerationist rhetoric that the Plan heralded the start of «a new century in which Costa's old dream can, at last, come true (...) the Ésera (The Ésera is the river that runs, going down the Pyrenees, through the birthplace of Joaquín Costa) and many other Éseras will flow over the skin of Spain and their clean waters will be its lifeblood, its dew, its gold, the path to collective liberation and wealth» [16]. Yet, contrary to both the first quarter of the century and the Franco years, over the last two decades a notorious absence of a 'hegemonic' project has been the main feature of the water political arena for reasons that are now reviewed.

Factors involved in the continuity of the hydraulic modernist project

This situation, characterized by the coexistence of contradictory ideas, projects and actions and the absence of a clearly dominant strategy, is the result of tension between factors of continuity and factors of change, both involving cultural, social and economic dimensions.

First, at the deepest cultural level, the mainstay of the resistance and continuity of the hydraulic model in Spain up to the present day is the perception of water, which Spain shares with other countries on both sides of the Mediterranean. Thus, it is considered a hostile medium, with dramatic swings between sometimes intermittent torrential water flows and extremely low water levels, which coincide precisely with the hottest season of the year.

The hostility of this water environment, however, can be transformed into splendor and beauty through human involvement. Hence, the estimation of human-made hydraulic landscapes (the *huertas* or orchards, *domesticated water*) as ideal images of the power of hydraulic engineering. Society delights in images of clean waters flowing in mountainous areas or springing from natural sources, places charged with symbolism and the backdrop to economic and cultural functions. However, the positive image of *domesticated water* as a basic feature of development overrides the negative image of impacts of the natural aquatic media, which is generally fluctuating, uncertain and threatening. In broad terms, Spanish society lacks a clear idea of a natural water environment against which to assess the excesses of transformation, when the traditional technologies of local irrigation systems (which actually created those highly valued landscapes) were substituted by the great works of modern hydraulics.

As late as 1996, the former mayoress of an important Spanish city and former Minister for Culture in the Spanish Government backed the idea that a new reservoir planned for a valley, which for once was well conserved and covered by national and international environmental and landscape protection measures, «would be positive for biodiversity, as it would contribute to maintaining green areas in the city». The concept of nature underlying these statements – clearly representative of the model for the link between nature and society inherent in the debate – is perhaps an extreme vision of nature as a social construction founded on the high social valuation of dominant *domesticated water* in Spanish society.

In the case of the reservoir mentioned above, the mayoress' opinion is even shared by the locals affected by the flooding of their lands, who look kindly on the creation of an artificial lake in their vicinity, although they will not benefit from the hydraulic resources created as a result. In addition to the jobs that would be generated as a result of its construction, it is understood that the infrastructure will allow for the development of leisure activities related to the reservoir. It must

Figure 2: The reservoir of El Portillo on the Castril River as as example of the strong hydraulic infrastructure system.

Figure 3: The dam and reservoir La Bolera on the Guardal River among more than 1000 big dams built in Spain over the last century.

be mentioned, however, that in other areas affected by plans for reservoirs, such as Santaliestra (Huesca), Castrovido (Burgos) and Genal (Málaga), there are signs of growing opposition.

Secondly, another factor of continuity in the hydraulic paradigm is the ongoing perception of *geographical imbalances* as major obstacles to development and well-being, which confirms and strengthens the idea of the transformation of nature, primarily the hydrological system, as a key feature of any modernizing political program. Once the resources of the driest regions are exploited to the limit and once the technology for long-distance transport is developed, the resolution of *hydrological imbalances* between river basins becomes an all-important objective. In fact, this topic holds the key to the debate in the most recent period of development of the hydraulic paradigm and it is conditioned by processes of changing scales in shaping decision-making bodies, an issue that is discussed in greater detail below.

Thirdly, the above-mentioned continuity can also be explained by the ongoing process of transformation of the actors that have controlled the country's hydraulic policy to date, that is, the *hydraulic policy community* [21]. This is a tightly-knit, fairly autonomous, highly stable policy network consisting of the main stakeholders involved in the working definition of the hydraulic paradigm: the main agricultural organizations, construction and hydroelectric power companies, the main water management authorities and the Engineering Corps [9,25].

The cohesion of the community was guaranteed by economic interests, the homogeneity of technical criteria and the fluency of contacts inside and through the public administration. The inclusion of new stakeholders and the exclusion of other traditional ones caused by changes of scale in the distribution of power, the fragmenting of prevailing interests and democratization, as well as new emergent values and social aims, have still not succeeded in completely undermining the strong cohesion of interests within this powerful group. As in other countries affected by the hydraulic paradigm, groundwater specialists, who have been mainly excluded from the hydraulic policy community, have severely criticized the predominant model of hydraulic policy, characterized by a lack of knowledge and respect for aquifers and their consequent mismanagement [13].

The panorama of continuity factors is completed by an ever-increasing demand for water for irrigation purposes, which still constitutes the main drain on resources (about 80% of total demand), and which retains, on account of the social, cultural, landscape, and even ecological role attributed to it by society, a great deal of the social *legitimacy* it has traditionally enjoyed [18].

Over the course of the last decade, there has been a significant increase in the total area of irrigated land, mainly as a result of private initiative, which, in the last few years, has taken over from public initiative in the promotion of new irrigation systems. This does not mean that the State has abandoned its role in large-scale hydraulic works, as can be inferred from the predominance of public initiative in the construction of reservoirs. At present, 87% (39,175 Hm^3/year out of a total of 45,034 Hm^3/year) of total water resources available in Spain are reservoir-regulated surface waters (Ministry of the Environment 2000). It should be pointed out, however, that the role of groundwater in recent irrigation projects is on the increase.

Processes of change towards a reflexive society model

In spite of the factors of continuity mentioned above, in recent years certain processes of change have eroded the cultural basis of the hydraulic paradigm. Such processes are, in fact, the regional expression (with specific features at a local level) of large-scale phenomena operating on a world-wide scale [17]. These factors of change include the evolution of values regarding nature which, although occurring later than in other countries (change in the *myths of nature*, according to Douglas and Wildavsky [5]), are now being introduced in Spain.

From the mid 1970s onwards, *insalubrious marshy areas*, which were still in the process of drying up, began to be timidly conceived of as *wet zones* of great ecological value. The rivers, which had to be channeled and, if possible, diverted away from populated areas, became spatial resources of great potential, especially for urban design and the image and promotion of cities. These new values are connected to other features of the *culture of the reflexive society* [2], which contributed to undermining some of the conceptions of the hydraulic paradigm.

Challenging the modern rationalist attitude, the roots of the ecological school of thought, which finds fertile ground in the *reflexive society*, are characterized by two basic precepts. While everything is inter-related, not everything is reproducible or interchangeable. As a consequence, the measurement of value and impact are (almost) impossible.

Therefore, a hydraulic project does not end with its planning, execution and operation, as modern reasoning would have us believe. Instead, «it is the source of an endless stream of impacts which, on being removed from their origin, grow and cross over disciplines and scales, contaminating local matters with global ones, and the present with the future» [29]. One of the reasons behind the slow transition of water policies in Spain is, precisely, an inability to quickly and easily accept the new values of nature that might lead to rejection of the visions of the *modernist hydraulic model*.

This progressive but difficult expansion of environmental awareness is reinforced by tendencies towards market mechanisms and the application of criteria of economic rationality to public investments. Nobody doubts that much of the pressure exerted on the aquatic environment would be alleviated, albeit perhaps sometimes traumatically, by applying the principle of cost recovery included in the Water Framework Directive of the European Union (WFD).

This is the reason why there has been a certain convergence of liberalization supporters and ecologists in their opposition to the traditional paradigm based on *state paternalism*, inherited from the old reform and social cohesion project by means of the hydrological re-balance of the country financed with public funds [11]. On the one hand, a system that recovers only a small part of the replacement cost of public investment made in dams and canals is condemned. Moreover, the substantial degree of water regulation already in effect – over 50% of renewable resources – places many projects in a clearly marginal position on account of a decline in their output. On the other hand, the distinction between economic demand, based on willingness to pay, and physical demand, based on stated needs, is called for [19].

The general rejection of the paternalistic and interventionist system in force has actually led to a certain consensus about the introduction of market instruments having positive effects on the management system as a whole, although it may only affect a small part of resources. The buying and selling of water rights would act, in the opinion of experts, as a mechanism for revaluing water as a scarce commodity and would introduce the economic dimension in the users' minds, making them think in terms of opportunity costs and levels of marginal productivity in water use. Putting in practice a system of exchanges among users would help to avoid water restrictions in places situated near irrigation areas. In this way, transfers between extremely distant regions would take second place as a solution to local water shortages. For example, 'aberration' is the word used to describe the transfer project proposed «from the headreaches of the Tajo to supply the municipalities of La Mancha and their protected nature areas, by means of a unified supply network, which has been planned without taking into account local resources and infrastructures, which are supplying enormous irrigated surfaces very inefficiently: for instance, a ton of water is required to grow a kilo of corn» [19].

Water liberalization has been the topic of heated debates, especially concerning the effect on social and territorial equity, as well as on the environment and the landscape. On account of historic tradition and a particular legal framework, in the Canary Islands there are various legal forms of water buying and selling in operation. This institutional framework, despite its well-known pitfalls [1], has a positive effect on saving water and the development of the purification and re-use of residual waters. However, even the most productive agriculture cannot compete with urban uses, mainly coastal tourism. The agricultural landscapes are therefore under threat. With this experience as a backdrop, left-wing political parties, as well as associations of small-scale and medium-scale farmers, and some ecological groups, have criticized the introduction of market mechanisms. Nevertheless, even from the viewpoint of these sectors, it is recognized that making the system of concessions more flexible (preferably through water banks, under administrative control) is considered a good idea because of its potential to reduce irrational uses, minimizing the social unrest in the course of a transition to more sustainable models.

Another weakening factor of the hydraulic paradigm is the crisis in financing for public works, caused by sustained efforts to reduce the public deficit, a decline in European Union structural and cohesion funds, which dropped by 25% for the period 2000–2007 in the *2000 Agenda* (the European Commission financial schedule for this period). Also the accession of Central and Eastern European countries to the European Union has added uncertainty concerning Spain's eligibility for such funds. This idea has been clearly expressed in recent times «the historical commitment on the part of state budgets to set up irrigation infrastructures no longer makes sense» [14, p.839].

Furthermore, the strength of Spanish irrigation (significant increase in land area, solid social legitimacy and strong presence of the sector as a political pressure group) contrasts with the reality of sectorial disunity and an uncertain future. An increasing number of studies [4] highlight the great differences in productivity, job creation and efficiency in the use of resources between different areas. It is important to point out the discrepancy between the 1.2 million hectares of newly irrigated land included in the River Basin Hydrological Plans for 2012 and the 0.2 million foreseen for 2008 in the National Irrigation Plan, which was drawn up in the same year as the others were passed (1998).

This is due, in part, to the varying representation of the Autonomous Communities, the agricultural lobbies and other pressure groups under the umbrella of the river basin authorities responsible, who tend to favor the greatest possible involvement in public investment and hydraulic resources.

Yet the Ministry of Agriculture, responsible for irrigation planning, is, on its part, more realistic and sensitive to the ever-increasing pressure of the World Trade Organization, the successive reforms of the European Union Agricultural Policy and the irreversible fall in the number of people actually working on the land (a decline of over 40% in the last decade) [26].

Attempts have been made to find a solution to this paradox by making the river basin water plan projections subject to «the programs, deadlines and projections established in the National Irrigation Plan (*Plan Nacional de Regadíos*) in force at any given moment» (Royal Decree 1664/1998 approving river basin water plans). In fact, this NIP is a planning instrument that is not considered in the State's legal framework, while, on the contrary, water plans – which should be drawn up in conjunction with the «different plans that may affect them» (article 38.4 of the Water Act) – are highly formalized, normative instruments. This has given rise to a peculiar situation, which has been described as «the progressive substantiation of a plan [the Irrigation Plan] without a specific legal basis» [7, p.92].

All these changes are interrelated and influenced by the transformation of the hydraulic policy community discussed above. The process is similar to what has happened in other countries. Fissures have appeared in the previously close-knit traditional community. Interest groups are divided and promote their interests more cautiously and prudently than they did before. Underlying this new situation are two structurally intertwined trends.

Firstly, there has been an increase in the number of agents involved in political deliberation: the *policy community* has become an issue network that is larger and less integrated than it was previously, with new actors that operate on a much more open, less stable public stage, a lack of consensus on the problems at issue and the means by which they should be tackled [21]. This increase has been caused by four interacting transformations in the institutional framework of political life: i) the restoration of a democratic regime, the subsequent development of the logic of competition among political parties, ii) the activation of public opinion and, very importantly, iii) the change in the political territorial structure of the Spanish State, primarily the emergence of the State of Autonomies (almost a federal model) and, iv) the growing power of local councils. These changes contributed to the appearance of new social movements and new representatives of local opinion and interests [25].

Secondly, the increasing importance of the role of the global scale (mediated, in the case of Spain, by the European scale) and the parallel rise in power of the regional/local scale in policy-making – already implied in the previously mentioned changes – should be emphasized as a decisive contribution to the amendment of the traditional arena of water policy. Globalization is rapidly introducing new conditioning factors of a financial nature (World Trade Organization), political factors (growing importance of EU legislation, especially the recent WFD) and cultural factors (dissemination of extra-Mediterranean values as criteria for the evaluation of water policy). Yet, the growing role of regional and local bodies in water policy makes the regional and local scale increasingly important as a privileged arena for confrontation and for the struggle for social support and political legitimization [30].

In view of the tumultuous history of the NHP, from the 1993 draft to its approval in 2001 and partial repeal in 2004, it seems clear that the politicians responsible for the initial proposal were making a grave mistake when they stressed that «It is not a problem that has to be discussed among autonomous regions, it is not a problem of the political division of the State, it is a question of the physical organization of the Spanish State» [3]. On the contrary, the political reality has shown itself to be more important than the physical reality: inter-basin transfers, when they take place within a single autonomous community, are less (although still very) conflictive than the distribution of water within a single river basin but between different autonomous regions. As Pérez Royo said, «if it had occurred to any of the members of the Constitutional Parliament [who established the present-day structure of Autonomous Communities] or to any of the commentators on the Constitution in 1977 to predict that in 1999 we would find ourselves where we are now with regard to the structure of the State, he or she would have been considered a visionary... And anyone who fails to see this has no business in politics» [27].

Final remarks

Over the last decade, the effects of an important change in the way water issues are addressed have made themselves felt in Spain. The dynamics of the situation make it risky to establish a definitive assessment of the final outcome of the changes. Suffice it to say that the topic of climate change, which is likely to have crucial repercussions on Spanish hydrology, has only just come onto the water debate agenda in Spain. Its implications in the medium-term may, however, be far-reaching.

With regard to operational considerations, the new water policy discourse comes up against one powerful obstacle in Spain: agricultural interests and the values of the agricultural sector still hold great sway over Spanish society. Furthermore, there has been much talk of the negative effects of cost recovery on different social sectors, especially agriculture. However, the latest reforms are bringing about a significant change in this situation.

The repeal of plans for the Ebro transfer constituted a historical milestone in Spain's long-standing hydraulic policy. The arguments raised to justify abandoning the plans were compelling: the 2001 NHP said the decree repealing the plan showed «significant and serious deficiencies» in fundamental economic aspects (exaggeration of benefits, systematic underestimation of costs, failure to explain price structure), environmental aspects (lack of measures to protect affected rivers, lack of measures to ensure the safety of protected species, ineffectual approach to salinity problems) and technical aspects (inaccuracy of studies on actual availability of water to be transferred) [15].

The partial repeal of the NHP coincided with the implementation of the new WFD, which requires this change in the logic of water policy and addresses the issues surrounding it. Concepts such as restoring the ecological status of water, responsibility for the cost of water resources, incorporation of coastal water management and active social participation are the pillars of the new legal framework. This is a change of strategy that entails a deep transformation of objectives, procedures, routines, professional manager profiles and type of social agents involved.

In support of, and beyond this new legal framework, there is an extensive process of reflection on water in the field of social, economic and environmental science, a rapid change in water treatment and purification technology and an important process of social awareness and mobilization in defense of waterscapes as the expression, in many cases, of the territory as a whole and of living conditions. As a result, water policy is perhaps the sector in which the shift towards sustainability strategies is most clearly formulated and has most specific technical and legal resources.

In any event, in view of the inertia shown by the system, everything points to competition for water resources continuing to increase in the near future in metropolitan and coastal areas, between urban, new and increasing environmental uses and agricultural demands, which may continue to expand in the inland areas of the large river basins and among different irrigation zones, in relation to their location, the types of crop grown, productivity and the efficiency of infrastructures.

The debate and conflict surrounding water quality will, in all likelihood, come increasingly to the fore, as will the opposition of local/regional communities on seeing their natural heritage spoiled for the sake of the development of production activities alien to them. In such a context, efforts to make the present concession system more flexible, develop mechanisms to reallocate water resources among users, progressively reduce administrative water supply allocations for irrigation and introduce incentives consisting of reduced rates for water-economizing practices are bound to succeed. How equitable the outcome is, what kind of economic efficiency is achieved, what the social consequences are and how the new structure of the power relationship for water will be forged will all depend on the definitive institutional framework in which the transition to the new management model takes place.

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Urban growth and changes in the role of the river system: the case of Seville, Spain

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Abstract
Changes in the role of urban rivers reflect the evolution of the patterns that define urban growth. Thus in order to understand the reasons for urban expansion and how it takes place is a good framework with which to analyse the different relationships between rivers and the city. This paper seeks to show, using the case of Seville (Spain), that using urban landmarks we can rebuild the historical relation between these vectors. This information will be very interesting in defining the future role of urban rivers, not only as environmental resources but also as social places.

Keywords: Urban growth, river, Seville

Introduction
Rivers are not only natural elements but social resources. Thus the parameters in which the relationship between society and rivers is formed offers useful insight into their role. This dialectic can be seen everywhere, but it is probably in the city that the intensity of changes and the double role of rivers as management elements and public spaces are clearer.

Throughout history, the physical and symbolic relations between city and rivers have varied as a result of cultural, economic, ideological and political factors. We can distinguish three principal paradigms:

The first, when the profits of urban rivers – supplying, productive and commercial activity, recreational space or cleaning – have been enough to outweigh the problems arising from natural hazards such as floods, health problems or difficulties in urban growth [4,5,6,7]. This is a social paradigm that dominates until the 19th Century.

The second begins when the urban pattern changes and the organic city is replaced by a planned city. Often this new urban concept is based on the will to surpass the historical limits of the city [5]. Therefore historical walls, rivers, etc., must be eliminated or controlled in order to build the modern city, and there is sufficient technical knowledge to do so. This paradigm produces a simplification of the multiple functions of rivers, which appears channelled and sometimes distanced from the urban texture.

Today this paradigm still works, but it coexists with the third that connects with the ecological conscience and the debate concerning quality of life and urban sustainability. Urban planning is beginning to incorporate these values, although sometimes more in a theoretical framework than in reality. On the basis of these new proposals, the city needs to rediscover its hydraulic heritage as a social, natural and spatial resource for urban renewal. This is a difficult process in which physical rehabilitation and citizen participation are of great importance [2,3,9].

Recognizing landmarks of the river–city relationship in Seville

A brief history of the fluvial area of Seville

The evolution of the river system of Seville has been very intense, mainly after the changes produced by the urban development that took place in the 19th Century. It is from that time that we can distinguish the transition between the social relationship and intervention in fluvial courses.

The location of Seville on the last promontory of the Guadalquivir basin and the confluence of several rivers (the Guadalquivir to the west, Guadaira to the south, and two streams to the east: Tagarete and Tamarguillo) is the first key to understanding the historical importance of the rivers of Seville, not only as threats but also as opportunities [3,9].

The Guadalquivir and Tagarete Rivers embraced the historical city which, until the 18th Century, was one of the greatest cities of Europe, with the principal port used for commercial relations with America). This historical configuration began to change due to the town planning projects of the middle of the 19th Century. These mark the beginning of a successive transformation of the both territorial and social relationships between the city and its rivers.

From that time, different projects have succeeded one another: Arjona (1847–1849), Sanz Larumbe (1926) or other modifications of the channels during the sixties and seventies. As is evident from figure 1, all of these changes are direct results of urban growth, first towards the south and later to the east, through a model that does not integrate fluvial channels within the city.

In the contemporary city this tendency has partially been stopped. It is not, however, verifiable in all cases, because while the Guadalquivir River has recovered its position as a main street and great public space, the image of the other rivers is still negative, and they do not show any collective uses.

A process such as this leaves several landmarks on the urban texture, many of them with a high heritage value. It is not, however, easy to understand them without paying attention to their origin and the way in which they represent a particular hydrological paradigm in Seville. Thus it seems essential to determine how the city grows, the urban model followed and the reasons for this. There are many places that show how a river loses its central urban role, but probably the borders of the historical city are the most striking example.

The historical city and the role of its rivers

The historical city was embraced by two rivers (the Guadalquivir to the West and the Tagarete to the East) which were simultaneously resources for life and dangers for health and personal property. In fact, in the 18th century the city wall did not have defensive functions but instead

Figure 1: Historical intervention in the hydrographic network of Seville

acted as protection against floods. With the same motivation, some buildings like the «Archivo de Indias» are built upon a series of steps that protect it from these floods.

If one looks at historical illustrations, one can recognize the intensive activity of the port, which is emphasized by the Gold Tower, and the singular space that this port area produces: the «Arenal», which is an urban ensemble that is nowadays overwhelmed. It nevertheless maintains its entire symbolic role on the border of the channel that reproduces the historical layout of the Guadalquivir River, no longer as a commercial but as public space.

On the other hand, the Tagarete River defines the border between the city and the Guadalquivir Valley. This strategic location is the reason why, despite its small size, there were up to eight bridges on this river. Nowadays, this stream does not exist; all that remains is its layout reflected on the streets, one of which is still called «Stream Street». The bridges have disappeared as well, including landmarks such as the «Alcantarilla de las Madejas», which was both a bridge and an aqueduct. It can be seen at the top right hand corner of the picture. Indeed this little river is a great example of the impact of the 19th century pattern of urbanism and how this is a parallel for a new paradigm defined by intervention on fluvial areas.

Figure 2: Historical view of Seville, engraving by Joris Hoefnagel, 1588

The city that forgot its rivers: Seville after the 19th century

When the expansion of the city was a reality, in the 19th Century, the urban landscape of Seville was radically changed. As can be seen in figure 3, the southern historical border and the «Arenal» disappears, and a new urban texture characterised by great public spaces and monumental architecture appears (San Telmo Palace at the bottom left of the picture, and the Old Tobacco Factory on the right).

The demands of the new social order led to a new urban concept. The bourgeoisie and aristocracy did not like the historical urban organization and desired a new one that was less compact and more functional and healthy. In Seville this new way of building the city is not as clear as in other European cities like Barcelona, because at this moment the city has lost its historical centrality. But up to a point the city develops to the South and to the East. Nevertheless, some authors say that the new city has been constructed just up the historical district, because of its great extension, as an urban reform [1].

The rivers that had delimited the city inside the walls are understood as undesirable elements because of floods, mobility problems, etc, mainly in the case of Tagarete. This one is vaulted and disappears from urban texture in south (and later displaced to the east). On the other hand, the Guadalquivir River is equipped with flood defences, and some notable public spaces have been built and improved along it. In this sense we can recognise a first sign of the current preference for the great river over the other rivers.

Once the rivers have been controlled, the historical wall loses its last importance and, following

Figure 3: Seville in the 19th Century

this new concept of the city, it was partially demolished.

Ironically, the role of those rivers as «impermeable» elements that configure the city is assumed by the railway, whose lines have a very similar location. This is the new landmark of the city in the 19th and most of 20th Century. As a result of this infrastructure, the Guadalquivir River remained partially hidden until the 1990s, when the works on the 1992 World Exposition led to the closure of the west lines and the restoration of a pedestrian avenue along the canal next to Torneo Street.

The challenge of the present city: to recover the fluvial system.

The present-day river system of Seville has two different faces. On the one hand is the Guadalquivir Canal that runs within the city, producing symbolic landscapes like that of Betis Street (Figure 4). It has recovered its value as a heritage landmark and a public space. However, it is not difficult to find maintenance problems or the use of part of the pedestrian avenue adjacent to the Gold Tower (another landmark of the city of Seville) for car parking. In addition, some old harbor zones remain closed and run-down, and their interest as didactic and heritage spaces are not considered. The rehabilitation of these places and their distinctive elements, such as the old cranes, could be a priority in the city's contemporary urban development.

On the other hand, the image of the other rivers and of the arm of the Guadalquivir River that runs naturally is much worse. They constitute an opportunity for the configuration of a necessary green system for a city in which metropolitan processes are evident. But this is not possible if they maintain their present level of degradation and if urban management does not give priority to recovering their lost central position.

Figure 4: Two different landscapes along the same river. Skyline of Betis Street (left) and historical dock area (right) along the Guadalquivir River.

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Doñana active dune system: an example of a fragile equilibrium ecosystem in the Mediterranean environment

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Abstract

Doñana National Park includes one of the most spectacular active dune systems in Europe. The extension of the system (about 60 km^2) and its impressive mobile dunes create a unique landscape, which represent one of the scarce natural dune ecosystems in the Mediterranean coast. In this sense, the system is an extraordinary field laboratory for coastal dune research, especially to evaluate those processes related to environmental changes, human actions and management policies and practices. The paper includes a brief description of the system and shows the first results of our research about its evolution from 1956 to 2000.

Keywords: Coastal dunes; mobile dunes; GIS; conservation management; environmental changes

Introduction

Coastal dunes constitute valuable natural elements from many points of view; these include, among others, their ecological significance, their role as a protective agent against coastal erosion, or their relevant landscape specificity. In spite of this, coastal dunes have been destroyed and occupied by man throughout the world [3]. In a first instance, coastal dunes were considered to be especially dangerous, mainly there where they showed rapid inland advances that affected agricultural fields, inland water bodies or villages [10]. To prevent this problem we find a series of actions that have been taken against natural dunes, consisting of vegetation planting; the first well documented action is attributable to Bremontier, who developed a method for dune stabilization by pine planting in Las Landes (France) at the end of the 18th century [7]. In a second instance, the solution of tree planting was seen quite soon as a resource; many hectares of bare sand could be converted into productive forest. Therefore, even in places where coastal dune were not a problem, they were treated by planting stabilizing vegetation. Finally, during the second half of the 20th century, dunes have suffered an accelerated process of destruction due to littoral occupation by the tourist industry, intensive agricultural fields or industrial complexes. In the last decades of the 20th century, national and regional authorities started to protect the scarce coastal dunes remaining in a natural state in Europe and especially in the Mediterranean. These actions are related to numerous scientific works, which call attention to the importance of coastal dunes as agent to prevent coastal erosion and as rich ecosystems.

In this context, the founding of Doñana National Park in 1969 implies the protection, among other environments, of a unique coastal active dune system in an area close to emerging tourist and intensive agricultural sectors. As one of the scarce natural coastal dune system in Europe, Doñana active dunes represent an invaluable field laboratory for coastal dune research from ecological and geomorphological standpoints. This paper on Doñana active dunes is focused on the application of GIS techniques to morphological and dynamic characterization of the system.

Study area

As showed in figure 1, Doñana active dune system is located at one extreme of the Huelva province on the SW coast of Spain. Geologically it belongs to a series of littoral formations representing the close up of the old Guadalquivir valley. The zone is said to pertain to an oceanic Atlantic-coast Mediterranean subclimate [8]; it has 500–600 mm annual precipitation, typical summer drought, and soft mean temperatures above 10°C any month of the year. As recently delimited [4], the system is about 60 km^2 and it extends along a 26 km shoreline and 2–3 kms inland. The system is said to be active since aeolian processes are dominant above other geomorphological agents. In this sense, the system is within a greater aeolian area (500 km^2) known as the Abalario-Doñana littoral aeolian mantle (MELAD), which includes other fossil and semiactive dune units where aeolian processes are no longer dominant above pedological, erotional or mass waste processes [2].

Looking at the whole coast of Huelva, we observe a continuum of estuaries and associated marshes from the Guadiana river mouth, at the Portugal-Spain border, to the Guadalquivir river mouth at the border between Huelva and Cádiz provinces. These estuaries are closed to the sea by different littoral sand formations, among which aeolian units are normally present as foredunes or small scale dune fields where littoral spits expand wider [2]. So, what are the reasons for such a great development of aeolian formations in the Doñana area? To answer this question, factors for coastal dune development have to be considered.

Coastal dune formation factors

Littoral dunes require two main factors for their formation on any coast of world: **1) a source of sand**, and **2) wind conditions** capable of moving the sand inland. If littoral dune fields are considered, a third factor is needed: **3)** a **suitable topography** behind the beach on which dunes can develop. Vegetation is not the main requirement for coastal dune formation, as proved by many bare sand dune fields along the coasts of the world, some of which are part of coastal deserts. However, apart of these special cases in extremely arid environments, **4) vegetation** is always present in coastal dune systems and constitutes one of the key elements for their specific morphology and ecological richness.

In Doñana active dune system all the cited factors are present as revealed in the following lines.

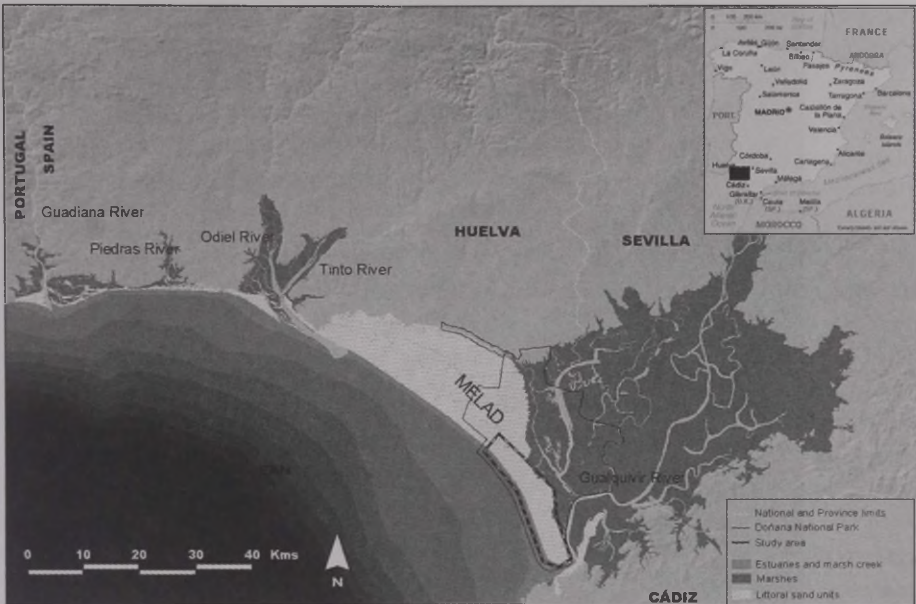

Figure 1: Localization of the study area on the coast of Huelva (SW Spain)

1. In respect to the source of sand, the system is located at the eastern extreme of the Huelva coast. This coast has constituted an entire littoral cell in which the alongshore drift has a net component to the east. Thus, Doñana's wide, accretional beaches represent a sort of sedimentary sink, where a great part of that drift arrives.

2. Over these wide beaches the wind blows strongly enough to move this sediment. The 26 km Doñana beach is aligned NW-SE, so it is an exposed coast in respect to the dominant SW winds associated with the arrival of south Atlantic depressions in winter and autumn. In summer and especially in spring, sea breezes may blow at considerable speed, high enough to blow up sand particles; the reason for this strong breeze is the great temperature differences between land and sea; wide bare sand areas reach quite high temperatures around noon, when the sea is still relative cool from the night.

3. Doñana active dunes traverse the Doñana spit. This littoral formation has been growing since 6000 years, closing the old Guadalquivir estuary. Except for the western extreme, where some old fossil dunes overlie the spit, the active dunes have developed over the spit's plain topography, which presents no important obstacles for inland migration.

4. Vegetation is present in the system from the first phase of dune formation at the back beach to the stabilization process of some inland dunes. Different aspects of vegetation are described later in the paper.

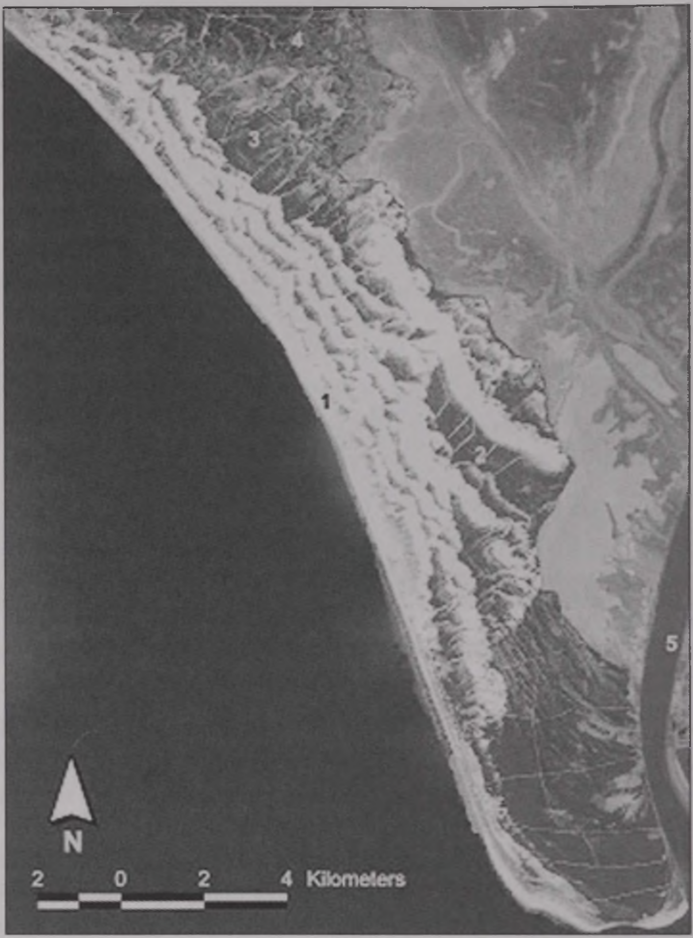

Figure 2: 1999 Orthophotograph of the Doñana active dune system 1. Dunes; 2. Slacks; 3-4 Old dunes areas; 5. Guadalquivir river.

Descripton of the dune system

Doñana active dune system, as shown on figure 2, consist of 4 or 5 parallel dune ridges (in white) separated by a series of interdune depressions (slacks). Slacks are areas of wind deflation and they represent the interval between ridge formations; the intense wind erosion is responsible for the proximity of the water layer, which at the same time explains the abundant vegetation [5].

Looking at figure 3, two different parts are distinguished in the system; the first one, corresponding to the area between letters A and B is the coastal complex, and the rest (C, D and E) is the inner complex.

Coastal dune complex

This part includes 4 different units; from the sea inland, these units are the beach, the foredune, the intermediate area and the first transgressive ridge.

The beach is obviously part of the system as it constitutes the source of sand feeding the dunes. On the back beach, pioneer vegetation species (sand catcher) such as *Eryngium maritimus, Otanhtus maritimus, Salsola kali* or *Cakile maritima* trap the sand and form the first sand mounds. However, the real dune builder plant is *Anmophila arenaria*, which is responsible for the first dune ridge formation (foredune).

The foredune (Fig. 3, A) can be a unique ridge, a set of ridges or a field of dune mounds. The dominant plant is *Anmophila arenaria*, which occupies the most exposed parts of the dune as is resistant to sand burial, wind action and salt spray. This section of dune has a steep wind side, which may be attacked by waves during storms, and a more soft lee side, where woody species (*Armeria pungens; Artemisia chitmifolia*) appear, since this is a less exposed environment. At the southeast extreme of Doñana, individuals of *Juniperus oxycedrus* can be found in this sector; this species constitutes a remnant of the old native forest destroyed by human uses of this area since the middle ages.

The intermediate area (between A and B in Fig. 3) is a sort of incipient slack. The water layer can emerge and hydrophilous plants may be present, although we rarely find the vegetation richness of true slacks. The reason for this fact is the continuous transfer of sand between foredune and the next inland unit (first transgressive ridge). This sand transfer is mainly produced through blowouts.

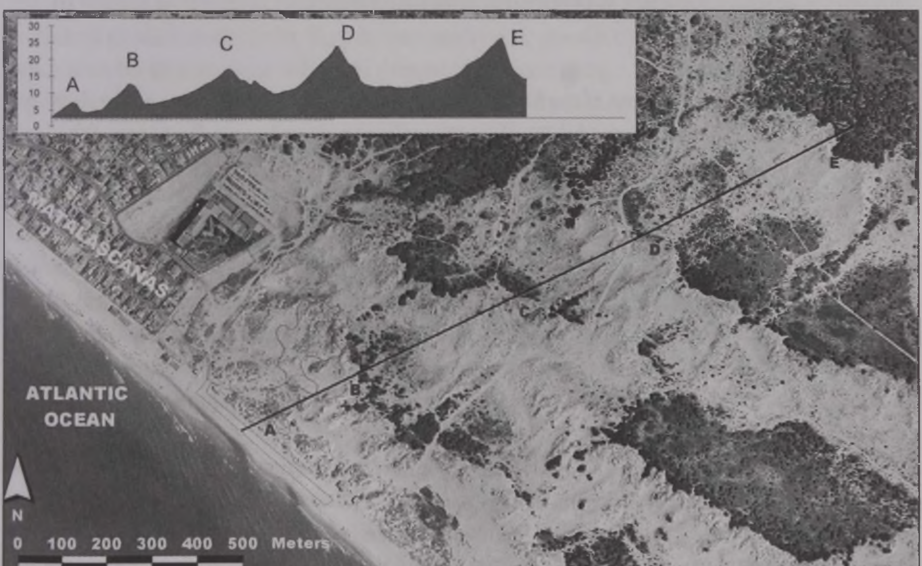

Figure 3: Doñana active dune system detail and topographic profile

The first transgressive ridge (Fig. 3, B) is a transitional unit between coastal and inner complexes and it has been frequently considered as part of the latter [4]. From our point of view, the above-mentioned sand transfer from the foredune might be assumed as a key argument for the inclusion of this unit in the coastal complex. The shape of this ridge is similar to the inner ones, which are described below.

Inner dune complex

After the first transgressive ridge, a wide slack appears that gives way to the inner complex. As shown in figure 3, the complex consists of a succession of slacks and dune ridges (C, D and E).

Slacks, locally called «*corrales*»(barnyards), are plentiful in vegetation, including different types of shrub species (*Juniperus phoenicea, Halimium halimifolium*) and tree species (*Pinus pinea*), and typical hydrophilous species when there are wet conditions (*Holoshoenus vulgaris, Erica scoparia, Calluna vulgaris*...). They show a plain topography, except for parallel undulating sand ridges (less than 1 m high) and isolated sand mounds. The first ones, called «*gusanos*» (worms), represent old positions of dune ridges fixed by vegetation. The second ones are remnant dunes that resist wind erosion due to the protection of vegetation in a particular place.

Transgressive dune ridges have a typical dune shape. The wind side has a soft, long slope from the tail to the dune crest, while the lee side level off with a short and steep slope. This dune front represents a key element that shows the advance of these mobile dunes; slip face lines can be followed for several kilometers as continuous undulating fronts.

Research findings

In this section we describe some of the first findings of our research on Doñana active dune system. Firstly, data and some methodological issues are exposed, and secondly, some of the most relevant results are commented.

Data and methodology

Basic data for the study is a set of orthophotographs from 1956, 1977 and 1999; for the 1999 orthophotograph a digital elevation model (DTM) has been built up using geomorphological criteria in the process of key element gathering (structural lines). ORTHO99 and DTM99 were used for characterization of the present state; from this set of data, dune system units were delimited and basic information was extracted, including topographic profiles (Fig. 3), slope maps, orientation maps and a series of morphometric indices for dune ridges.

The use of ORTHO56, ORTHO77 and ORTHO99 allows information extraction on the evolution of the dune system. Two main analyses were carried out: 1) the first one concerns changes occurring in the areas of dunes and slacks; by delimitation of these basic units on the three dates, areal comparison was made to see if variations in the distribution of units occurred; 2) the second one deals with dune advance rates; by photointerpretation of slip faces or dune fronts on the three dates, advance rates were calculated for the same points for the periods 1956–1977 and 1977–1999.

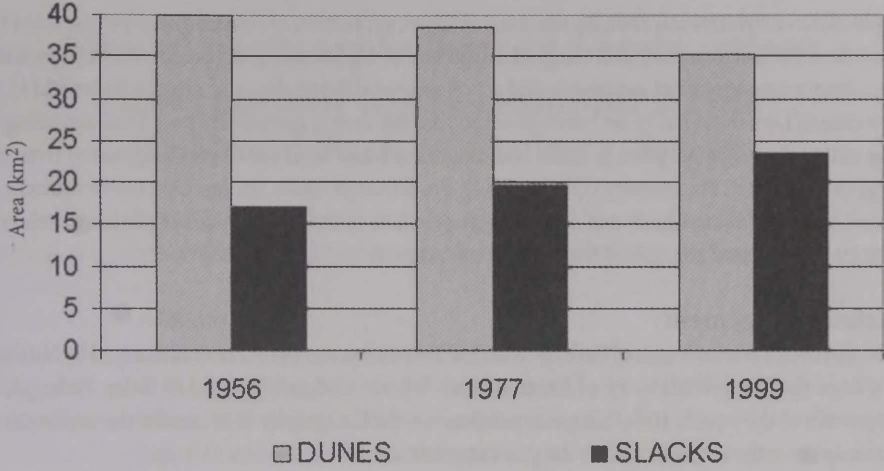

Figure 4: Superficial changes of dunes and slacks from 1956 to 1999

Results

Results of the evolution analysis are briefly presented below:

1. In respect to the areal comparison, figure 4 shows clearly the reduction of dune surfaces compared to slack surface. So, despite the continuous growth of the coastal dune complex by beach accretion, inner dune ridges are progressively narrowing.

2. Concerning the advance rates, the results show a decceleration of movement during both periods. From 1224 measurement points along slip faces, the average advance rate goes has reduced from 2.4 m/yr to 1.1 m/yr.

Conclusions

From the obtained results in the evolution analysis, some points can be brought out:

- Doñana active dune system shows an increment in vegetation cover from 1956 to 1999.
- This vegetation increment is reflected in the growing surface of slacks inward from of the inner dune ridge, which has experienced a progressive narrowing.
- Probably due to this vegetation increment, the movement of dune fronts is suffering a slowing down process.

The significance of these detected processes is not clear, nor so are the reasons for them. Results could be contradictory to data from climatology and ecology studies which show some evidence of warming in the area from the end of the 19th century [9]; this should bring more arid conditions and then a reactivation of dunes. If this warming is taking place and the system is less active, as our data shows, we may assume that there may be other reasons to explain this paradox. In this sense we have opened a line of research to study similar processes occurring in equivalent environments; thus, on the coast of Israel, protection of coastal dune systems from the middle of the 20th century and the gradual decline of traditional uses (especially cattle pasture) has encourage vegetation expansion and a progressive slowing down of mobile dunes [6,11]. In the case of Doñana it has to be borne in mind that the area is completely protected according to the national park declaration in 1969, and that many traditional uses have disappeared from the beginning of the 20th century (Ojeda, 1987). So, although these are not conclusive remarks, it could be argued that policies and management practices in the Doñana area might have a relevant role in the detected changes of the active dunes system.

Acknowledgement

The works in Doñana National Park are within a Research project (44/2003) authorized by National Parks of the Spanish Ministry of Environment. We are sincerely grateful to Belen Pedregal, as organizer of the Seville 10th European Seminar on the Geography of Water for the invitation to participate in the seminar and in the present publication.

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Fluvial geomorphology and restoration: low reach of the Guadiamar River, National Park of Doñana, Spain

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Abstract

We report on the results of our studies of the hydrogeomorphological dynamics in the environs of Entremuros (low reach of the River Guadiamar). Three basic morphohydrological units have been found in the this sector, which is affected by high tide and gulder as well as flood discharges, generating particular dynamics surrounded by man-made elements. A passive restoration has been taken on for the different morphological features like «lucios» (cuvette decantation), «vetas» (levee), cuvettes, lateral banks,... in the guadiamar floodplain located in the Entremuros area.

Keywords: fluvial geomorphology, passive restoration, Guadiamar River, National Park of Doñana

Introduction

The mining spill on to the River Guadiamar at Boliden-Apirsa was considered one of the largest natural disaster in Europe in the last years [1] due to its magnitude (over 5 millions m^3 of toxic residual deposits like mud and acid water) and size (4,000 ha). In 1999 the Consejeria de Medio Ambiente undertook the restoration of the damaged sector by founding a new protected area named «Corredor Verde» (the Green Corridor) [2]. The closed area of the National and Natural Park of Doñana was selected to implement the scheme. This is the Entremuros area, where the acid water was stored to stop it reaching the National Park of Doñana.

This scheme aims to restore the geohydrogeological function of the marsh of the River Guadiamar according to three basic principles: the ecological integrity of the fluvial system and its geomorphological formations [3]; the potentiation of the dynamic component of the fluvial process (hydrical flows and sediments) and finally, to improve understanding of a passive riparian system of the main morphohydrological elements [4]. Our task focuses on the last two terms, introducing our research procedure in order to identify and analyse the main morphohydrological units and their functions in discharge and sediment dynamics from the last reach of the Guadiamar for passive restoration.

Field of research and method

The catchment area of the River Guadiamar is located in western Andalusia and extends some 1,285 km^2 between the northern foothills of the Sierra Morena and the southern depression of the River Guadalquivir (Figure 1b). It lies 60 kilometers from the western side of Seville and the last important tributary of the Guadalquivir flows on its left side for 120 km. Its average roughness is 415 m. It is a Mediteranean-Continental climate river with an Atlantic influence, and that means: a warm temperature, 569 mm rainfall a year, 5.48 m^3/s of average discharges and extreme torrents (500–700m^3/s of Qmax) that promote periodical floods in the low reach of the marsh of the Guadalquivir. The studied area is located in this low premarsh environment (35 m.o.s.l.) of smooth hillocks of Plio- Quaternary sand which is found in the marsh of the Guadalquivir. This lies within the National Park of Doñana and it is named «Entremuros» due to its walling in the 1960s (Figure 1a).

We started doing our research into the situation of the marsh in 1956, before the main man-made changes, like the building of two one-kilometer-wide walls of sand surrounding the flood-stage and a drainage channel within the River Guadiamar. Geomorphological cartography has been carried out at a scale of 1:30 000 by photointerpretation of the flight on 6 November 1956 and by later comparing it with the digital ortophoto of 1:8 000 scale of the flight on January 1999, as well as our fieldwork.

Analysis and results

The results of research into the situation of Entremuros in 1956 by identifying morphological elements on the map (Figure 2) highlights the mixed ecodynamic performance of the area, from a more continental stage to a more estuarine stage, depending on the discharge and the sedimentary charge from the Guadiamar, the Guadalquivir, and « Arroyo Majaberraque», as well as on the position held by the tidal obstruction inside the Brazo de la Torre. Three morphohydrologhical units can be found as follows:

A. La Tiesa–Vado de Don Simón Unit.

It is the most northern Unit and extends from the confluence of the River Guadiamar and the Stream Cigüeña and the Stream Cañada Honda to the confluence between the Madre Vieja del Guadiamar and the Stream Majaberraque. It is formed of a sequence of braided channels resulting from the considerable sedimentary accretion of small materials (sand and silt) from the Guadiamar. There is a sector of high group-sinuosity braided channels joined by sand-silt deposits (crevasse splay) obstructing and bypassing waterways. Another dynamic distortion element is the hydraulic drainage elements in agricultural activities to avoid inundation and instability in channels from the proximal floodplain. This unit is affected by ordinary increases in the main discharge. We understand that overflowing in stratum generates a crevasse splay in this near/proximal sector.

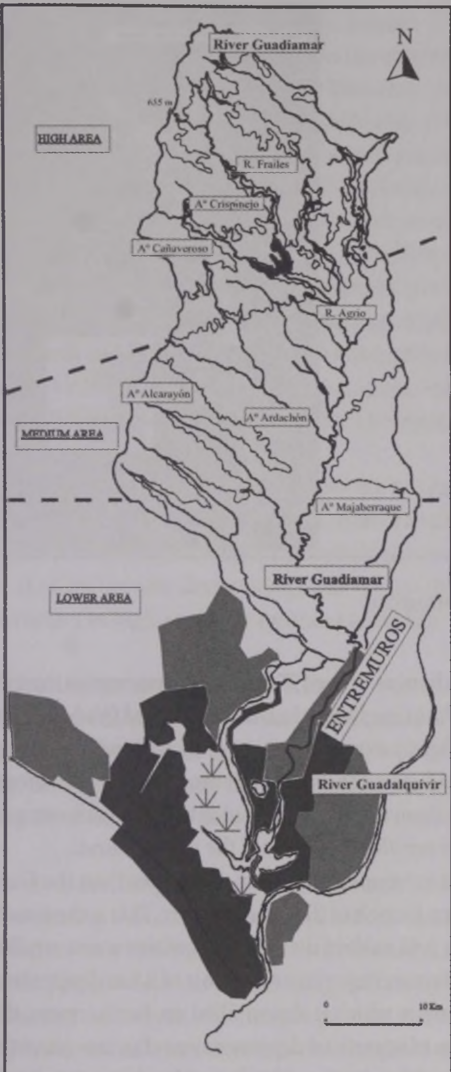

Figure 1a: Basin of the Guandimar River and situation of the Entremuros area

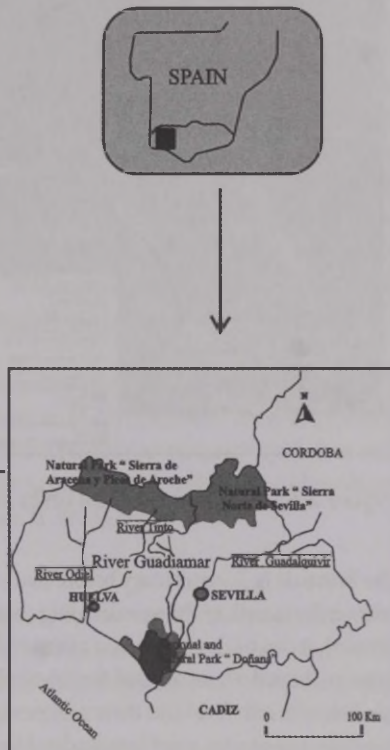

Figure 1b: River Guandimar in the western Andalucia

B. Brazo de la Torre–Norte de la Vuelta de la Arena Unit.

The calibrated bed of the Brazo de la Torre forms this unit, and it was the original location for the transition between the continental geomorphological domain of the River Guadiamar and

Figure 2: Morphohydrological units in Entremurous

the Brazo de la Torre estuary before man-made changes in the 1950s, reaching at nearest the tide impact the mouth of the new draining channel of the Guadiamar in Don Simon ford (Vado de Don Simón). It can be described as a calibrated and slightly winding bed and it is surrounded by many lagoon-shaped elements and fluvial-tidal lateral banks. These smooth morphological elements are below marsh level and their sediments come from a bank. The rapid action of overflowing in meanders generates a net longitudinal limit between these banks and the level ground.

The morphometric characteristics of this unit are similar to higher discharges than the Guadiamar, revealing an ancient origin as an estuarine branch of the Guadalquivir. This is the reason why the later filling by the Guadiamar (less than 5.48 m^3/s of discharge) contains a new smaller (width and depth) channel. Its ancient channel plays an important role. Most of it has disappeared due to agriculture activities, except the main segment, which is almost filled up. Furthermore, the channel from Brazo de la Torre generates a system of superficial depressions or «Lucios» (cuvettes decantation). They are located both in the proximal floodplain and in lateral banks retaining rain and floodwater from freshets. Therefore we are dealing with geohydroecological valuable seasonal lagoons, which control hydrical and sedimentary excess from alluvial systems.

The overflowing discharges settle suspended silt loads near the active channel, between lateral deposits and «lucios» (cuvette decantation), creating levees that are less than 50-cm-long extensions with smooth lateral slopes. They play a double role as sediment controllers and provider elements with hydrical flows in the floodplain. In this way, levees are essential morphological elements for retaining the morphological continuum of the river, as well as its spatial dynamics.

C. Vuelta de la Arena–Southern Sector.

It lies in an area full of meanders in the eastern marsh of the Guadalquivir, from the Meander Vuelta de la Arena to the Meander Matochar near the mouth of the Guadalquivir. Its dynamics changed in the 1950s when its natural outlet through the Brazo de la Torre to the Guadalquivir was closed with a part of the Levant wall and an artificial channel (low discharge) was built in order to drain the active channel of the Guadiamar. This channel flows close to the Levant walls by the Meander Vuelta de la Arena and meets its mouth in the Brazo de la Torre in the low reach of the Matochar. As a result, the Caño Travieso area and the ancient marsh surrounded by the walls have turned into a cuvette decantation for freshet, giving the floodwater a double function: first, overflow lamination and sediments storage and decantion; afterwards, discharging water to the north and the east once the level decreases in the active channel from the Brazo de la Torre in the Vuelta de la Torre and in a man-made channel. Two morphohydrological sectors can be found before the ordinary movement of hydraulical flows in the Brazo de la Torre has been altered by the Levante wall. We deal with:

The Brazo de la Torre area lies from the Vuelta de la Arena to the Matochal. It is hydrologically a functional area of both ordinary fluvial discharge regime and tidal dynamics. There is an abundance of lateral banks, original morphological elements from this fluvial-estuarine system, as well as «lucios» (cuvette decantation) and «vetas» (levee) due to ancient channel fills or sedimentary dynamics in high-sinuosity meander areas like Vuelta de la Arena.

Discussion and conclusions

The longitudinal and transverse performance of Entremuros shapes smooth morphological profiles, where roughness can vary from a few centimetres to some meters. The main energy in the fluvial system originates from the flow inertia instead of the topographic gradient. The following two situations can be defined in the Entremuros area:

A. Low discharge dynamics and processes.

Concerning the ordinary discharges of the Guadiamar and its tributaries, the hydrical dynamics comprise only of the active channels. Nowadays they are formed by the man-made channel and its surface height depends on the rising tide storing fine sediments on it by sliding and flocculation. Draining discharges, obstruction process and rotary sliding in the left bank of the channel are otherwise found when there is a low water level or ebb tide. These dynamics took place throughout the channel of the Brazo de la Torre before 1956, as its lenght and width most likely promote the interaction of the continental and tidal flows. Thus, we guess that the fluvial riparian system must lead to a recovery of the original situation, before the area was enclosed by the Levant wall.

B. High-medium discharge dynamics and process.

On one hand, the effects of low flood flows depend on tidal level, causing overflowing through and over the lateral banks of meanders. These banks function as a «flood channel» and generate the minimum space for «fluvial freedom». On the other hand «mantle» flood dynamics appear from the north to the south on the proximal plain when there are higher than 500 m^3/s flood discharges. These dynamics appear once the active channels and lateral banks are filled up. Both flows and sedimentary discharges are controlled by «vetas» (levees), whose position is in turn controlled by ground geometry and roughness.

But today the longitudinal profile has been changed by transverse buildings that accumulate a vast amount of sediments on channel and lateral banks. Its amount is gradually increasing by the approaching Vuelta de la Arena. The longitudinal profile has changed from Vado de los Vaqueros, promoting a flow removement to the headwater once the rising wave inertia is over. Re-establishing the main original components implies that the transversal channel profiles recover a low discharge and the hydromorphological process is activated

From all the above, we maintain that the recovery of the original dynamics must be aimed at the passive riparian system of the centimetre morphologies in the lateral banks and floodplains («lucios», cuvettes, «vetas» and lateral bank scarps) and in the channel, obtaining the optimal section of its hydraulic radius (perimeter, width and depth).

Acknowledgements

This work joins the research project on «The geomorphological dynamics in the River Guadiamar and its banks in order to fulfil an ecodynamical riparian system of its channel and alluvial plain» by PICOVER , Conserjeria de Medio Ambiente, Junta de Andalucia and the HUM- 697 Research Group «Geografía Física Aplicada y Patrimonio».

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Drought management in Andalusia, Southern Spain

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Abstract
Spain is the most arid country in Europe, which means that drought has become an everyday phenomena in many areas and has social, economic and physical repercussions, especially in the southern parts of the country. Since the drought phenomenon begins with a deficiency of precipitation, Andalusia and the Mediterranean areas suffer from a regular lack of precipitation and high temperatures causing evaporation and problems of water quality. This can not be considered only from its physical aspect. In this case, drought represents an especially difficult situation for agriculture and socioeconomic activities. The aim is both to manage agriculture for export and to protect water resources for the population.

Even if the topic affects an important socio-economic sector in the South of Spain, authorities did not expect worsening situation to take measures. The high number of artificial channels and reservoirs demonstrates the typical water management policy. The available water resources have to be shared with agriculture, industry, tourism and domestic water consumption. Many questions are unanswered; this paper tries to deal with some of these urgent issues.

Keywords: Andalusia, water scarcity, drought, drought management, socio-economic impacts, legal background

The definition of drought
Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. Defining drought is therefore difficult; it depends on differences in regions, needs, and disciplinary perspectives. In the most general sense, we can state that drought originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. It is clear though that drought cannot be viewed solely as a physical phenomenon, it is a much more complex social-economical feature as well, having interaction with almost every aspect of human activity. If we have a look at another approach, we can say that drought is a temporary aberration; it differs from aridity,

which is restricted to low rainfall regions and is a permanent feature of climate. Examining the disciplinary perspectives on drought, we distinguish four kinds of water shortage:

1) Meteorological
2) Hydrological
3) Agricultural and
4) Socioeconomic

Problem description

Our research activity is based on the fact that Spain is the most arid country of Europe. As a result of problem, the country has the largest number of large dams in the world and the country uses the lowest proportion of groundwater for urban supply.

Derived from the natural water shortage and from supply problems, together with the needs of modern society, the government created a National Water Plan in 2001, in order to regulate water supply in Spain. The creation of the National Water Plan is well justified in the country since the average precipitation is 700 mm/year, showing a huge spatial deviation from almost oceanic to semi-arid and arid areas. We also have to state that evapotranspiration is higher than precipitation due to social and economic utilization. Spain's current water uses are about 33 km^3/year, which is an average of almost 3000 m^3/person/year. Based on the above-mentioned problems, our paper deals with the vulnerability of the Mediterranean ecosystems concerning the following main units:

- Increasing risks
- Social, Economic and Legal concerns
- Agricultural issues

Social and economic aspect of drought

Recent sustainable development concepts are searching for some kind of functional equilibrium between the environmental, social and economic interests in the society. There are many different examples, exploring the negative and positive aspects of the practical results of these concepts. However, the south of Spain is a region proposing to meet the challenge of maintaining this artificial equilibrium between the environmental concerns (precipitation levels) and the social and economic development levels (agriculture specialization).

In fact the seminar results and the statistics we used show that water, as a resource in Andalusia, exists in great quantities, despite of the low mean rainfall (between 70–300mm for over 75% of the territory of Andalusia). Indeed, this circumstance leads us to rethink our initial questions concerning the phenomenon of drought in this part of Europe. No doubt the scarcity of water is a fact from the point of view of the increasing water demand. As a result the big dams of Andalusia are not effective enough measures against the natural irregular hydrological regimes in this region. The water scarcity and the natural result of «drought» is aggravated by the necessity for irrigating water at the period of the lowest rainfalls. According to the data analysed, over 80% of the dammed water goes to the agriculture sector – cereals, grapes, sugarcane, citrus, greenhouse raspberry and tomatoes and irrigated olives. The rest of the water resources are «sufficient» to serve all the other needs of the economy.

The Andalusian economy remains less efficient in comparison with the rest of Spain. The GDP per capita is still 25% under the national average. Andalusia's value added share is about 14%, making the area an important Spanish region, but structurally underdeveloped [5]. The tourism sector generates over 70% of the value added and modern industries are located only into the Seville–Huelva–Cadis triangle. In the south the primary sector plays the leading role due to the reserves of pyrites, lead, coal, copper, iron and zinc, and the business connected with their extraction. This further deepens the inter-region polarity. On the other hand, the agricultural sector generates 6.5% of the value added and employs 11% of the labour force, indicating low productiveness of the sector. Despite this, Andalusia accounts for a large part of the Spanish agriculture export.

This data show that water is mostly consumed by the non-efficient agricultural sector, which is, however, an important employer and exporter. The EU Commission and DG Regional Policy defined Andalusia as an Objective 1 region (GDP per capita is below 75% of the EU average). Because of that, the future structural aid will promote the strengthening of growth in the economic sectors that are more vital (SME's, information technologies, water management, rural development etc.). In addition the INTERREG III and URBAN II initiatives are applicable. They create the opportunity to employ more people and to raise the incomes and economic diversification. According to us this is one of the things that will increase water consumption in non-agricultural sectors, which at this time are using water more efficiently. The EMASESA (Empresa Municipal de Abasteciminento y Saneamiento de Aguas de Sevilla) experience shows very interesting data. They have raised the water price several times, but the water consumption still increases. In a short time, if this tendency continues, the incomes from metropolitan-used water and agriculture-used water will be very similar and other public and branch organizations will sharpen the problem.

The preliminary seminar data demonstrated that residential and domestic water consumption is increasing faster than the human population in Andalusia. At the same time the growth in the main water consuming sectors (irrigated agriculture) is increasing together with the increasing share of new plantations. So, we may conclude that water scarcity will increase proportionally with the economic growth of all sectors. Hence, Andalusia's society may be faced with the decision of how fast its economic policy, supporting the quite often ecologically unsustainable service sector (dominated by tourism), food processing industries and the supplementing construction sector, must be reorganized. The seminar field trips discovered powerful non-governmental resistance to some «new development projects», which may affect water issues. Of course, the new businesses will change the situation on the labour market and after a certain time will certainly result in an increase in wages. This will most strongly affect agriculture sector expenses, where a comparative advantage is gained through relatively low labour expenses (lowly-educated immigrants). In fact at the moment we can identify powerful resistance to some of the economic transitions under the cover of environmentalist ideas but aimed at keeping the fragile social structure.

In conclusion, we may say that water scarcity and drought will not result in famine in the South of

Spain, but may create security problems regarding additional lagging in the food processing industries, social vulnerability and loss of cultural identity (traditional crop rotation and production chains). Traditional crops and the associated processing industries are closely connected to the local way of life.

The legal framework in water management

The first Earth Summit held in Rio de Janeiro in 1992 represented a turning point in the way we look at the environment and the development of water resources. Agenda 21 was formulated on order to strive for sustainable development in the 21st century.

In Europe, drought is an important issue of sustainable development. That is why many measures have been created for managing water resources. In fact, European water directive obligates countries to reach a «good status» on water quality by 2015 and addresses both environmental and developmental issues in an integrated manner at global, national and local levels.

In Spain, water management is not decentralized enough, however, municipalities have competences to manage water. This problem involves different actors such as authorities, committees, corporations and associations that have to be coordinated in order to elaborate common politics and strategies of intervention.

In the case of Andalusia, when drought is present, two subcommittees are founded: one concerning resources, in which the Andalusian Water Agency and the Hydrographic Confederation of Guadalquivir are members; and one concerning demand, in which we can find the consumer associations, the parks and the garden committee and the firemen. In serious drought conditions the Andalusian regional government and the central government are involved too.

Shall we have to overhaul water supply plans in these serious circumstances? In regard to demand, people try to intensify the information campaigns encouraging a water saving policy on a public institutional level and on a private level too, with the aim of reducing consumption by 5 percent. Moreover, sanctions are taken against those who waste resources and a possible correction of the scale of charges is considered. Naturally, in serious or prolonged drought conditions, these measures are strengthened with an increase in sanctions and a possible rationing of water supply during some definite hours of the day.

Contradiction between global and local policies

Even given the positive assessment of the management techniques in Seville, we believe that its social-economic development model should be reconsidered. In fact, there are many cases in which there is a conflict between the traditional uses of water resources and the new ones that are promoted to serve new tourist attractions, such as golf courses, swimming-pools etc. These water uses, however, are incompatible with the local hydrological and climatic situation.

A practical example is the situation experienced in the town of Cuevas del Becerro, where the inhabitants, the town council and the environmental associations are on one side and the tour operators and the estate agencies on the other. We can find similar conflicts in the agricultural sector as well, particularly among those who use well-watered cultivation models and those who would like to use traditional dry agricultural models.

Water management by EMASESA and policy in drought period

In the specific case of the regional centre of Andalusia, Seville, EMASESA (Empresa Municipal de Abastecimiento y Saneamento de Agua de Sevilla), the public utility company that manages the water supply, has the task of coordinating the different actions on water resources.

The two principal aims of EMASESA are:

1. The control of the integral water cycle (catchment, purification, distribution, recovery and reutilization of water)
2. Management of drought situations and prevention of future ones.

Two different instruments are used by the company to fulfil these tasks. One of them is the Manual de Sequía, a handbook that contains all the directives and strategies useful in situations of a crisis, and a GIS in permanent development. This latter system allows an even more efficacious monitoring of the entire distribution network in order to achieve quick interventions in cases of water leaks.

Figure 1: The logo of EMASESA [4]

EMASESA works at two levels (supply and demand of water).

Water supply requires:

- Inventory of resources
- Assessment of qualitative and quantitative levels of these resources in relation to situations of drought
- Assessment of different costs (catchment, distribution, etc.)

The water company of Seville decides which of the resources should be used regularly and which should be kept to face drought periods.

Water demand in drought periods

Two plans of intervention are expected: one concerns only the company and its internal organization, the other regards the relations between the company and the consumers. The first plan is more technical and it consists of interventions on the continuous renewal of the distribution network. Also the creation of a linked water distribution network in order to maximize monitoring and minimize water wastage is essential. The second plan includes education and information campaigns for inhabitants, schools, officials and technicians of the public administration and, on the other hand, scales of charges that provide a progression of water costs based on the consumptions and on the addition of a surcharge, intended to cover the higher costs of drought periods.

The Manual de sequía of EMASESA's identifies five situations – normal state, watchfulness, alert, drought, serious drought – specifying the interventions on a political-organization level and those concerning supply and demand corresponding to each state.

Conclusions

In this article we aimed to introduce and summarize the specific water usage practices of Andalusia, southern Spain, especially focusing on drought and its socio-economic effects. We provided an insight into both the legal and economic background of the phenomenon, proving that drought seems to be much more complex than just a deficiency of precipitation or, in other words, it is not just a single physical phenomenon. Since southern Spain is also an important resort for tourism, it is clear that – in parallel with the growing population – water management practices in Andalusia will be some of the most important actions of the local governments and the population as well.

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The most intensive droughts in France and in the department of Loire since 1985

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Abstract

The years 1985–1986, 1989–1991, 1997 and 2003 can be considered as the most severe drought in France and in the department of Loire from the year 1985 until the present day. Their occurrence is not regular from a chronological point of view, and we have to consider both annual events as well as multi-annual events. The multi-annual events can be as intense as annual events, with high temperatures linked to a low level of precipitation, but can have long-lasting effects on the socioeconomic context of a large territory. The environmental consequences are a deficient water quality, with less oxygen in streams, but also within water reservoirs, where the biodiversity is poorer. What to do to limit drought impacts? Besides restrictive measures applied during the event on an administrative territory such as the department, shall we have to manage hillsides? Is it a question about the forecast of the event, which is a particularly difficult theme?

Keywords: Drought, hydrological drought, meteorological drought, quantitative hydrology, water resource management, bath water quality

Introduction

With the precipitation since 1985 in France and in the department of Loire, the outputs of streams during the same period, and the consultation of newspaper articles and publications since twenty years ago, we can consider three main periods: 1985–1986, 1989–1991 and 2003. Other drought events would also have been considered in the years 1976 and 1997.

The summer of the year 2003 was in the major part of France one of the warmest and driest summers the country has known since the year 1976. The phenomenon was national and was felt also in the department of Loire. Can we consider the drought occurrence in 2003 as all the other drought episodes? Are there other phenomena like this one? With what severity do the droughts in our region arise, how do they appear, what are the effects of the drought on the political, economic, and social programmes? What are the environmental impacts we can find? Is there an evolution between the drought events and the impacts on the society according to the years?

This is the map with the names of the areas of this publication:

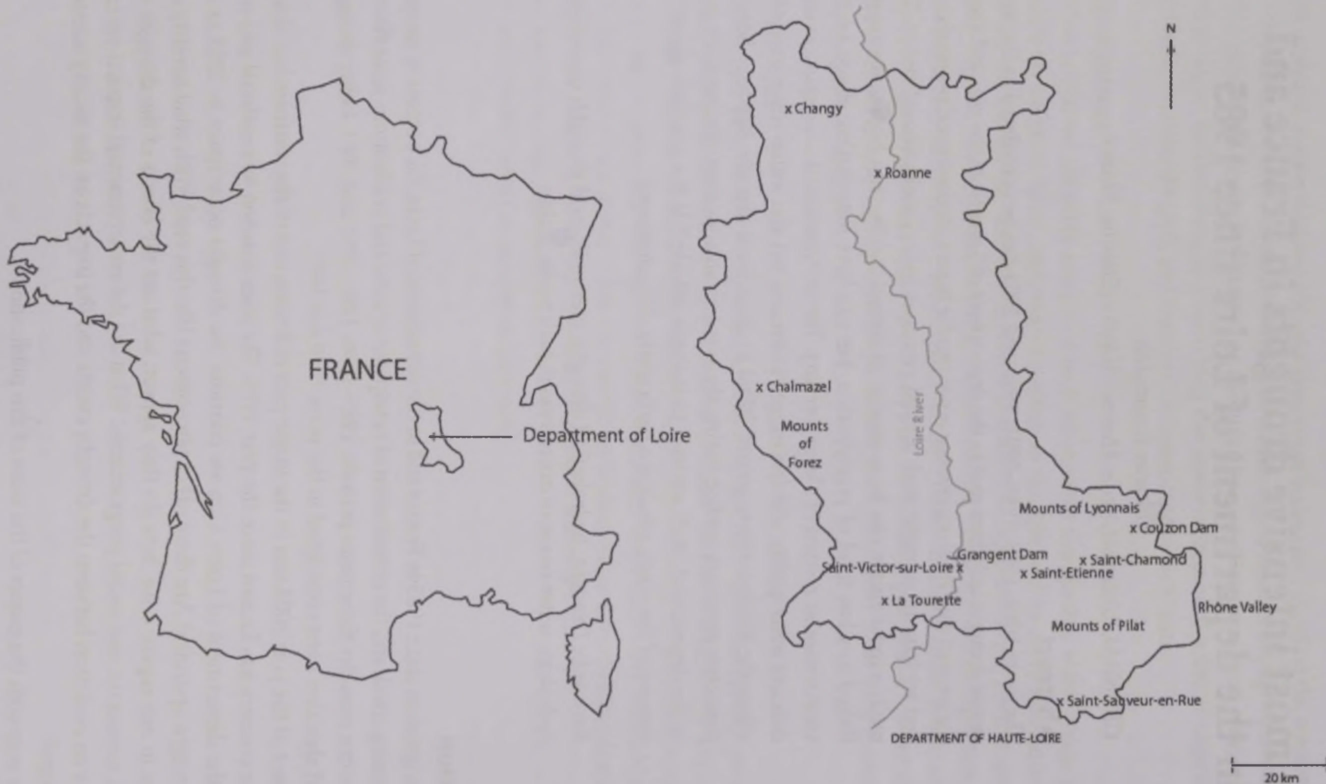


Figure 1: Localization map of the department of Loire in France, and names of places mentioned in the article

Drought cases since 1985

On the national scale, the years 1984–1986 and 1989–1991 represent multiannual phenomena. During multiannual events, groundwater levels cannot recover from one year to the next. The consequences on the hydrology are less spectacular than during the annual events of drought, but the impacts on the economy, notably in agriculture and breeding are graver, because they are echoed from one year to the next. 2003 is one year of relatively short but intensive drought, between March and October, with very high temperatures. Temperatures with more of 104°F in places at the end of June and during the first twelve days of August constitute records.

Between January 1st, 1984 and December 31st, 1986, the amount of precipitation was lower than normal throughout the department of Loire. The North of Roanne and the «Hautes Chaumes» of Forez are the most affected sectors and received an amount of precipitation that was less than 85 per cent of the normal. The foot of the Mountains of Forez, in the northwest of Saint-Etienne, is a privileged region, because it was little affected by the drought, with precipitation greater than 95 per cent of the normal. It is a sector irrigated by the water of the reservoir of Grangent, situated on the Loire river. This region is one of the driest in France (less than 600 mm of annual precipitation) (Fig. 2).

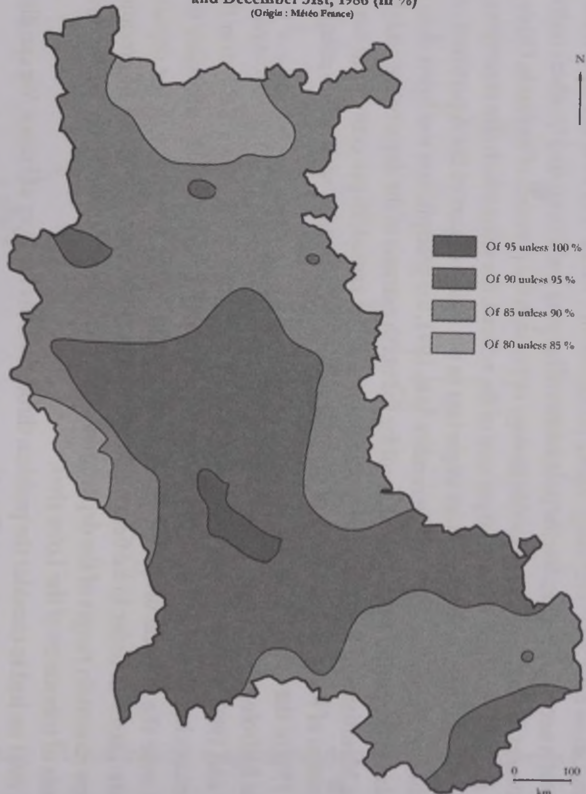
For the same period, the outputs of streams measured on the various stations give uneven results. Two stations show results greater than the normal values: near the Teyssonne river in Changy Village, in the region of Roannais, and near the Lignon of Forez river in Chalmazel station. Paradoxically, these are places where the pluviometry was relatively weak with regard to the normal between January 1st, 1984 and December 31st, 1986. (Fig. 2) The studied period is relatively long (3 years) and does not show extreme events (very strong precipitation), which may have occured in the region. Maybe it is necessary to mention the possibilities of keeping water in ground in others sectors of the department through a more favourable geology or through the presence of wetlands. Other stations show an average output of about 80 per cent of the normal, the value which also corresponds to the deficit of precipitation; this was more important in the southern part of the department of Loire.

Between January 1st, 1989 and December 31st, 1991, the precipitation was lower than normal, and also in the period 1984–1986. Except for the north extreme of the department and the sector of the Mountains of Lyonnais, the precipitation did not exceed 85 per cent of the normal. The Mountains of Forez and the south of the Pilat suffered in particular, with rates sometimes lower than 75% of the normal (Fig. 3).

The hydrological drought is more between the years 1989 and 1991 than between the years 1984 and 1986. Stations situated close to the Loire river show weak values of the river flow, with sometimes hardly more than 50 per cent of the normal (Fig. 3). It would be necessary to observe what were the impacts of the meteorological drought on the Loire river in the department of «Haute-Loire» in order to be better able to interpret these data. The deficit of precipitation in the low mountain ranges of the department of Loire can be understood from the low level of the outputs of tributaries of the Loire river.

In 2003 we had to consider the problem throughout the territory of France. We can distinguish three different zones in France (Fig. 4):

Report in the normal of the height of precipitation between January 1st, 1984 and December 31st, 1986 (in %)
(Origin : Météo France)



Report of the river flow between 1984 and 1986 with regard to the module in the department of Loire
(Origin : National network of data on water)

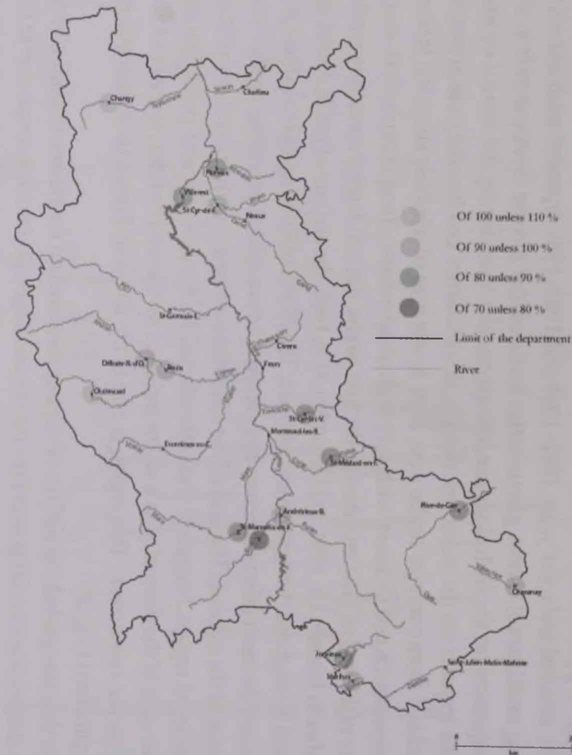
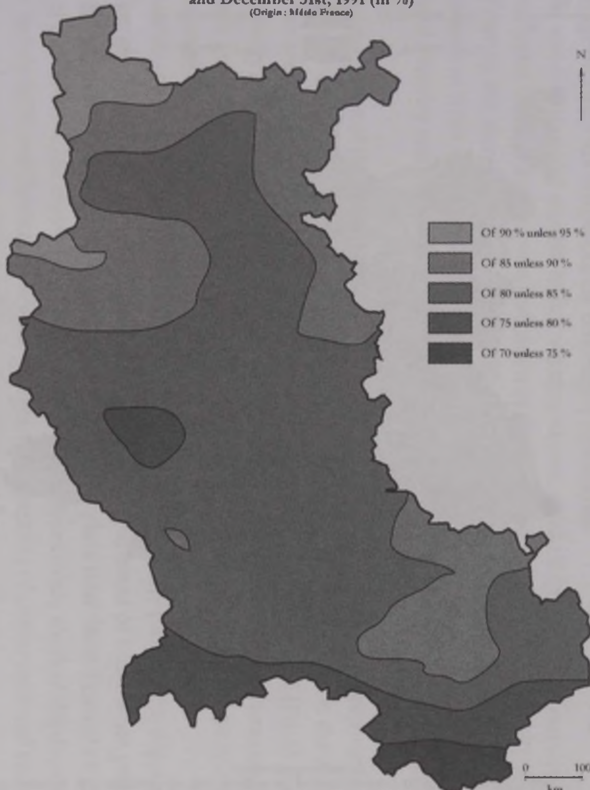


Figure 2 [6,7]

Report in the normal of the height of precipitation between January 1st, 1989 and December 31st, 1991 (in %)
(Origin : Météo France)



Report of the river flow between 1989 and 1991 with regard to the module in the department of Loire
(Origin : National network of data on water)

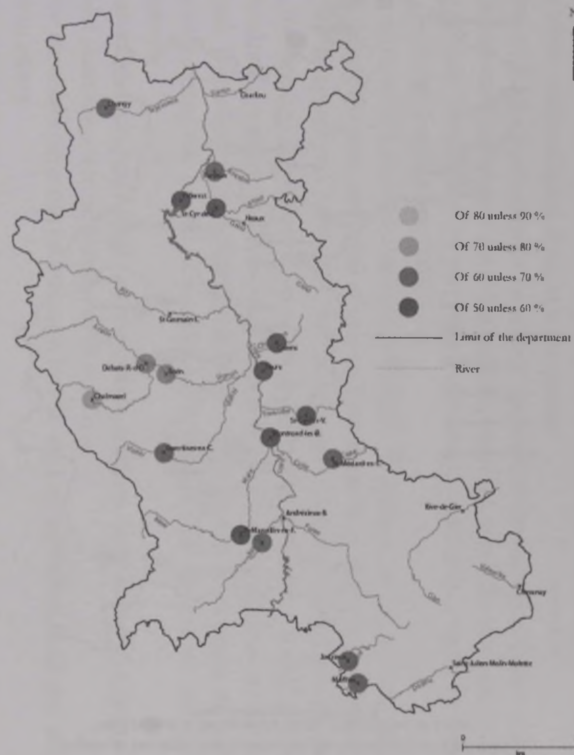


Figure 3

Report in the normal of the height of precipitation in the year 2003 (en %)
(Origin : Météo France)

Report of the river flow between the hydrological year 2002-2003
with regard to the module in the department of Loire
(Origin : National network of data on water)

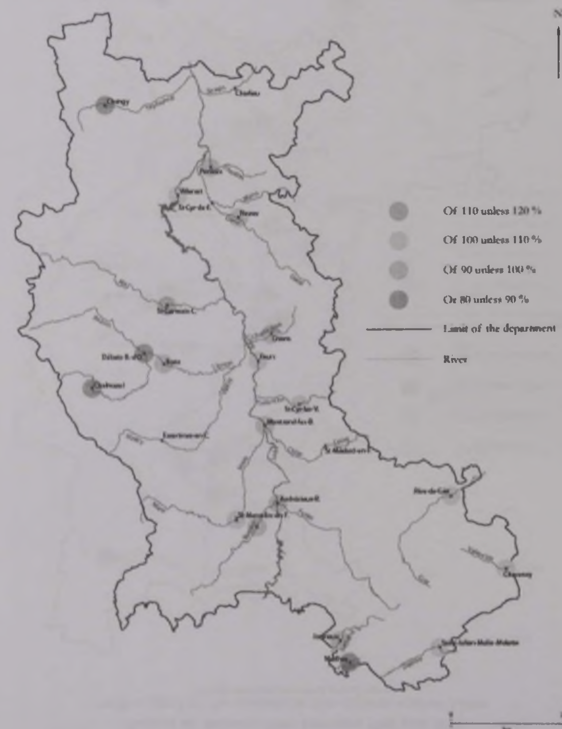


Figure 4

• The northeast quarter, with a deficit of precipitation sometimes bordering on 50 percent, it is the sector where meteorological drought is the gravest

• The West, with a total precipitation between 75 per cent of the normal and the normal

• The Pyrenees and the regions close to the Mediterranean Sea, where the total precipitation is greater than normal. The whole of the year 2003 is considered, and this zone had very important rainfalls on December 2nd and 3rd, 2003.

In the department of Loire, the Pilat and the region of Roanne appear as those with the least rainfall during the year, with rates of precipitation lower than 75 per cent of the normal. During the hydrological year 2002-2003, that is between October 1st, 2002 and September 30th, 2003, the streams of the Mountains of Forez and to the west of the Massif of Pilat are the most overdrawn in water. Streams from the east of the department show results nearer to the normal. Were the precipitation in the Rhone valley and in the Mounts of Lyonnais more important during this period ? Considering the information we have we have to keep to the hypothesis.

The intensive meteorological drought corresponds logically on the ground with a hydrological drought. Local situations are to be distinguished as follows:

• Some low mountain range can present capacities for the keeping back of water that are more important than others

• The precipitation can be uneven from one massif to another one

• It is necessary to take into account also the impact of human consumption

The environmental impacts of drought episodes

A lack of water associated mostly to hot weather shows a deficit of oxygen in streams and a decline of water quality. Bathing was forbidden in the lake of Grangent, near Saint-Etienne city, notably during the summers of the years 1985 and 1986. During summer the tourist demand is the greatest in front of growth of seaweeds in the lakes. It raises a sanitary problem but also one of civil security since the visibility in the water must be sufficient to be able to authorize bathing.

In the department of the Loire there are other reservoirs opened to bathing, on stream tributaries of the Loire or Rhone rivers (Déôme river near Saint-Sauveur-en-Rue's village, in the Massif of Pilat) or on special reservoirs (near La Tourette Village, in the Mounts of Forez) (Fig.5). Bathing was repeatedly forbidden during the summer period. During low-water periods, streams do not have much purifying power and the question of agricultural, industrial, and urban discharges in reservoirs arises.

The Southeast of France is subject every year to fires of variable severity (notably the departments of Bouches-du-Rhône, the Var and Alpes-Maritimes). The department of Loire is not protected from these phenomena and numerous outbreaks of fire took place near Saint-Etienne city in the middle of the 1980s. A fire crossed the South of the Pilat, in the extreme south of the department of Loire, in July 2000 and threatened several villages. The necessity of conservation of reservoirs for firemen and maintaining open landscapes is essential to face the threat.

Figure 5: Saint-Victor-sur-Loire city's beach

What to decide in front of drought situation?

Faced with the consequences of the drought of the year 1976, French authorities set up a «drought tax», which became a reference in unpopularity. Other episodes comparable to the drought in the year 1976 were not followed by new taxes, but by the institution of prefectorial orders.

We could not obtain enough data for the years 1985–1986. On July 19th, 1989, 26 French departments were affected by a prefectorial order aiming at the limitation of certain water uses, only in the West of France. Were the precipitations of oceanic origin really lower than the normal during the hydrological year 1988–1989?

September 11th, 2003, 74 French departments were under a prefectorial order aimed at limiting certain water uses. All the regions Limousin and Picardy, but also and especially the departments of Bouches-du-Rhône, the Var and the Maritime Alps were not subject to any limitation, even if the precipitation over the year 2003 was lower than normal. Is it about a political forecast in regions where tourism is a major branch of industry? The limitations were maybe also applied previously, the precipitation at the end of summer maybe being sufficient?

The current situation

On June 16th, 2006, 18 French departments were subject to a prefectorial order that was aimed at limiting certain water uses (Fig. 6). We distinguished several levels of limitations, although

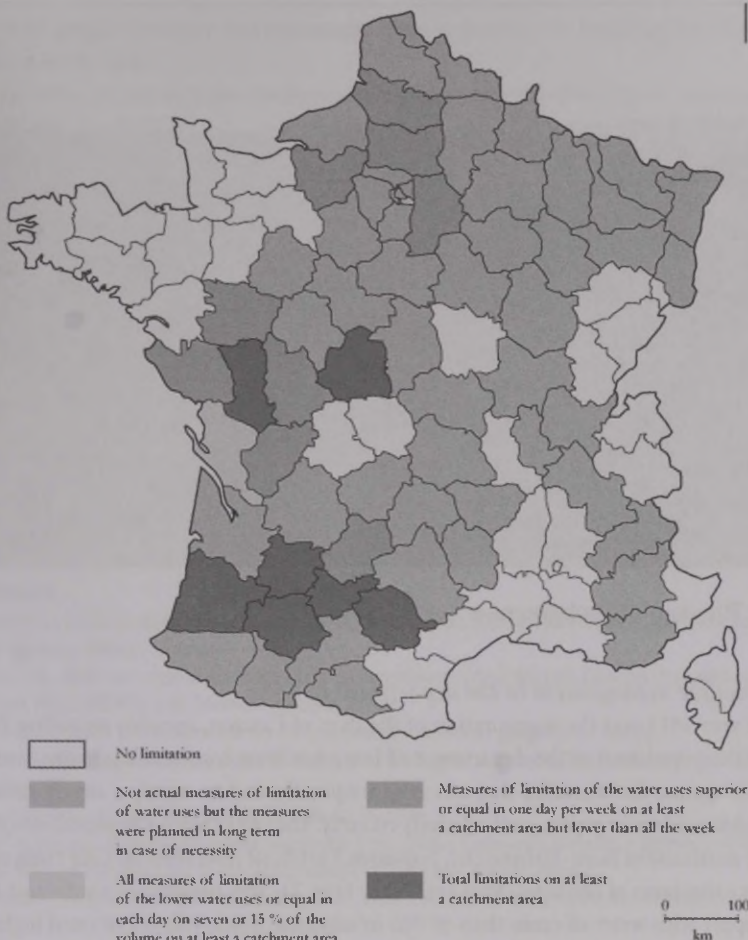


Figure 6: Measures at limiting water uses, June 16th, 2006

this was not the case in previous years. The West of the French territory saw particularly austere limitations imposed.

During various times water uses were affected. Priority is always given to drinking water supply. The weakness of the pluviometry affects the animal breeders of the department of Loire, who seek assistance from the animal breeders of other departments for the provisioning in hay. Between the years 1985 and 1986, and between the years 1989 and 1991, this situation was echoed from one year to the next. Besides the low level of precipitation, which directly causes a decrease in economic output, drought is the cause of indirect economic consequences. The impact can last several months, even after resumption of precipitation, even from one year to the next.

Figure 7: The dam of Soulages near Saint-Chamond city

Water resource management in the department of Loire

Since the year 1811 and the inauguration of the dam of Couzon, concern regarding the water supply of the population of the department of Loire has been constant. Their aim is to protect themselves against the scarcities that can arise frequently, and to supply a steady resource for factories that used water power until relatively recently. The city of Saint-Chamond, situated in 12 km in the northeast of Saint-Etienne city, possesses 3 artificial reservoirs on Gier river, upstream to the city : the dams of Soulages, Rive and Piney (Fig. 7). This constitutes a sufficient resource for the supply with water of more than 40 000 inhabitants. Some villages situated higher know severe water limitations, with sometimes a total exhaustion of water resources.

Above technical and environmental constraints imposed by the maintenance of various reservoirs, notably for the drinking water supply, the interconnection between networks is privileged. Since the year 1945, Saint-Etienne city benefits from a sufficient water resource thanks to the dam of Lavalette, situated in the department of «Haute-Loire». The transfers of water between hillsides, imposed by a drought situation in the year 2003, pose the question of the dialogue between the various actors and the water users.

The department of Loire has to face the problems imposed by growing construction, notably around Montbrison city, at the feet of the Mounts of Forez. In this geographic sector the precipitation is naturally low, and the growth of the population is continuous. The construction of private housing estates results in an elongation of networks, notably for drinking water supply, which increases costs. The elected members have to face a double pressure:

• the demographic pressure that encourages them to pursue new domestic flat construction, far from the workplace

• the pressure connected to the management of a water resource that is more and more limited and sometimes insufficient

Conclusions

The aim of this study was to prepare a comparative method between various times when droughts took place at the same time during the year in the national territory and in the department of Loire. We observed that for drought episodes as significant as those between the years 1985 and 1986, between the years 1989 and 1991, and during the year 2003, the drought impacts on the hydrological scale, but also has economic, social and environmental consequences. This can arise after a considered period, and sometimes over several years. In term of risks, the flood impact can be spectacular and its effects appear immediately. We can easily recognize areas damaged by flood episodes. When we study a drought episode, the difficulty is focused in the forecast, in the geographic area of the event, in its characterization in different points of view (meteorological, hydrological, agronomic), and in its long-term impacts.

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Drought and floods in Estonia – preconditions and impacts

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Abstract
The article gives an overview of some drastic climatic and hydrological conditions in Estonia and their impacts on human activities. Although small in area, Estonia's weather and consequently hydrological conditions vary considerably, temporally as well as spatially. Despite the prevailing temperate climate and absence of regular extreme weather conditions, droughts and floods occur practically every year. According to studies, the number of extreme days in a long time-series has increased, especially in the last decades. Examples are given in the paper, representing the territorial and temporal differences of precipitation and river runoff. Some extreme cases are described. Impacts of drought and floods are considered, pointing out the problems largely brought along by deteriorating drainage and irrigation systems.

Keywords: Water scarcity, drought management, floods, impact on agriculture, water management in transition countries

Introduction
Estonia is small in area (ca 45 000 km^2), but climatologically large. Its location at the junction of maritime and continental climates causes high temporal and spatial changeability of weather conditions. The important influences on the climate are the Atlantic Ocean (North Atlantic with Gulf stream and Iceland minimum) and the Eurasian continent [3]. Differences in precipitation, temperature and other climate characteristics are considerable between the western and eastern parts of the country. Variances in the volume of summer precipitation can reach a factor of 15 or more (e.g. an extreme case in August 2002 when precipitation in Valga county, southern Estonia was 0 mm; in the same month in Kuusiku, western Estonia, 88 mm).

Though extreme meteorological and hydrological conditions in the summer period are not typical from year to year in Estonia and generally do not cover the entire territory, floods and/or drought appear almost every year and are mostly unpredictably, causing problems and damage in agriculture and daily life.

Estonia is located in a climatic region where the yearly rainfall compensates possible evaporation (average annual precipitation is 626 mm, average 116 days with rainfall (data for 1961–1990, [7]); there is somewhat less precipitation on the coast and islands of western Estonia. 65–70% of the rainfall is in the warm season, with a minimum in March and maximum in August [5].

Thus the causes of summer droughts and floods mainly lie in the precipitation regime, as well as in the catchment and weather conditions prior to drought/flood, ground cover and the capacity of the water network to convey the runoff. The most frequent cause of floods is receiving more precipitation on a flat terrain than the ground can absorb (ground is saturated with water) and the rain water does not drain or flow away as fast as it falls. Despite the fact that the landscape characteristics of the region substantially prevent the formation of floods (majority of the territory is natural, numerous bogs absorb rainfall, few surfaces with solid cover, rivers are not limited with artificial banks [2]), strong rainfalls tend to cause a rapid rise of water level in rivers and the flooding of extensive areas.

Droughts are brought on by lack of precipitation – its duration, timing and distribution regarding water supplies, necessity and usage. To some extent the large percentage of bogs covering Estonia mitigates the impact of droughts by supplying water to rivers in the dry period.

Data

The criteria of meteorological drought and flood conditions differ greatly between countries, depending on the prevailing climatic conditions. Thus a single definition cannot be used. Some examples of the different definitions of drought:

- Great Britain (1936) – amount of precipitation during 15 consecutive days below 1/100 inches;
- United States (1942) – less than 1/10 inch of rainfall in 48 hours;
- Libya (1964) – yearly rainfall less than 7 inches;
- India (1960) – seasonal rainfall less than twofold average deviation;
- Bali Island (1964) – six days without precipitation [6].

For Estonian conditions the following criteria of agrometeorological drought and flood have mainly been used for analyzing extreme conditions:

- flood – precipitation 10 mm and more during the given day and the preceding 9 days, i.e. during 10 days;
- drought – precipitation on a given day and during the preceding 19 days less than 0.1 mm [4].

Data for drafting the current overview of hydrological drought and flood in Estonia was compiled from the available databases of the Institute of Geography, University of Tartu. Data included the long time-series of specific runoff (1924–2004) for the selected Estonian river basins (in all, data for 12 river basins was viewed) and precipitation data from 48 meteorological stations across the country. The selection of river basins was made on the basis of the geographical location of rivers with an aim to cover both the western and eastern part of the country.

Specific runoff of the selected rivers was calculated ($Q = l \cdot s/km^2$) for the long time-series as well as for the summer months (June, July, August). The years 2003 and 2004 are brought out separately to illustrate the extreme conditions. Corresponding trend surfaces reflecting rainfall for the years 2003 and 2004 were interpolated from the data of 48 meteorological stations. To determine the amount and trend of flood and drought days throughout the long time-series, the number of days in one year with Q 200% above and 80% below the long time average level respectively was calculated. Graphs and maps were prepared using MS Excel, ArcGIS and Adobe Illustrator.

Drought and flood frequency

Extreme climate characteristics, incl. the frequency of drastic conditions in precipitation (excess and scarcity of rainfall) and fluctuations have been studied in Estonia during a long time-period.

On the basis of previous studies of long-term time-series (ca 1922–2004) of precipitation in Estonia, it has been found that (based on the abovementioned criteria of agrometeorological drought and flood):

- the number of extreme days during the surveyed period has increased – studies of drought, flood and extreme days caused by precipitation during the years 1922–2004 in Pärnu (western Estonia, coast) and Jõgeva (central-eastern Estonia) have shown the increase of days with excess rainfall and drought since the end of the 1980s;
- the importance of drought and flood days in extremes has been different - increase in the number of flood days has been greater during the recent years [4];
- days of excess rainfall occur only in the warm season: in central Estonia (Jõgeva) from June to August, in western Estonia (Pärnu) from June to October. Days with scarce precipitation are distributed more evenly throughout the year [5].

At the same time, the global circulation models presume an increase in the amount of precipitation (varying 5-30%, mostly remaining in the range of 10–20%) in Estonia, but the increase is expected to be in autumn. Based on the models, runoff in summer will decrease and will increase in winter; thus the seasonal distribution of runoff is expected to level off [1].

The results of the current calculations of specific runoff are presented on the map (Fig. 1) and in the graphs (Fig. 2). The results confirm that the specific runoff depends on the amount of rainfall. The distribution of yearly precipitation (consequently also river runoff) throughout the country is random – drought in the islands does not imply the same in southern Estonia.

An example of the notable territorial and temporal differences is presented on the map of summer 2003. In August 2003 a cyclone following a prolonged drought period caused heavy rain and extensive flooding in the north-eastern part of Estonia (Fig. 3). For example, in Jõhvi region there was 177.4 mm of precipitation during 5 days, which is more than the long-time average norm of 2 months (86 mm monthly average). Floods in that region caused by heavy rainfall are also reflected well in the hydrograph of Purtse river (catchment PURTS008), where approximately a tenfold increase (from 7.6 to 58.4) in specific runoff occurred within 2 days. The precipitation in 2003 was higher than usual in Narva-Jõesuu, Viljandi and Võru. At the same time, western-Estonia and the islands suffered from drought.

The year of 2004 was again quite different (seen on the map in the left corner of Fig. 1 and hydrographs) – a flood in the capital city Tallinn was caused by heavy rainfalls in the northwestern part of Estonia. On 28 and 29 July, approximately the average monthly precipitation was received in Tallinn on both days. The heavy rainfalls are also expressed on the hydrographs of the rivers in northwestern Estonia (Keila, Vihterpalu, Kasari). The rest of

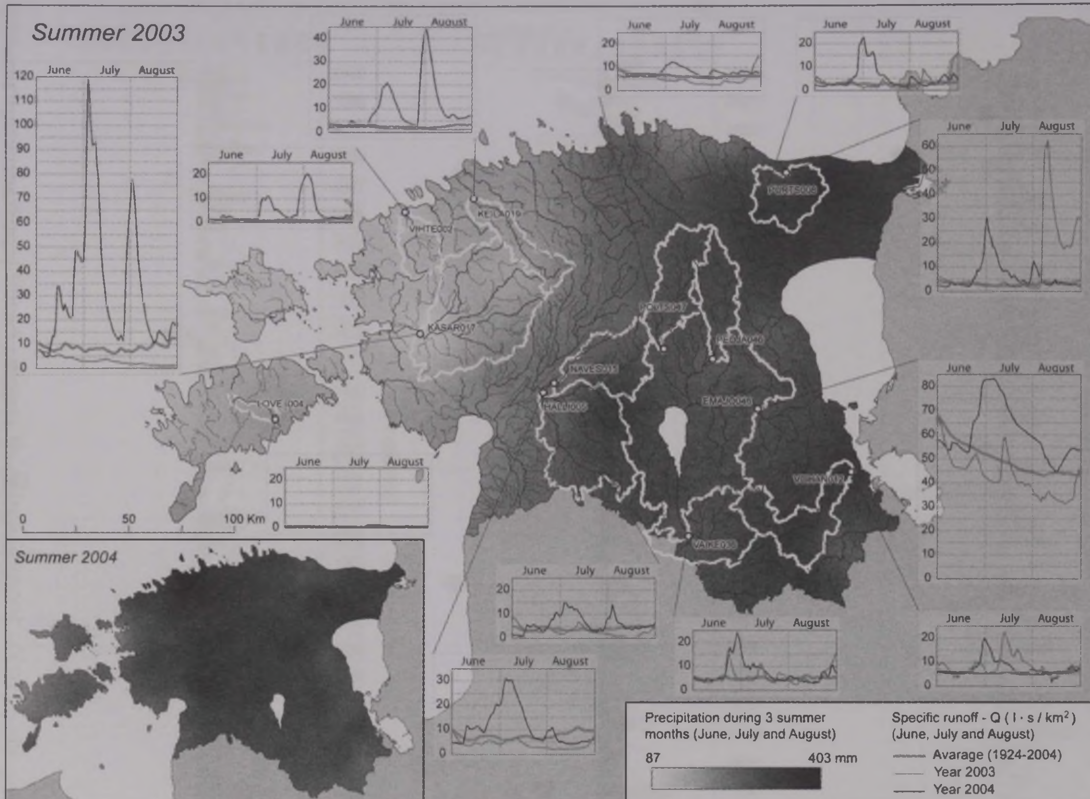


Figure 1: Precipitation in summer 2003 and 2004 is indicated in the map backgrounds. Hydrographs illustrate the specific run-off in summer months (June, July, August) on average and for the years 2003 and 2004. The connection between the amount of precipitation and specific runoff is apparent.

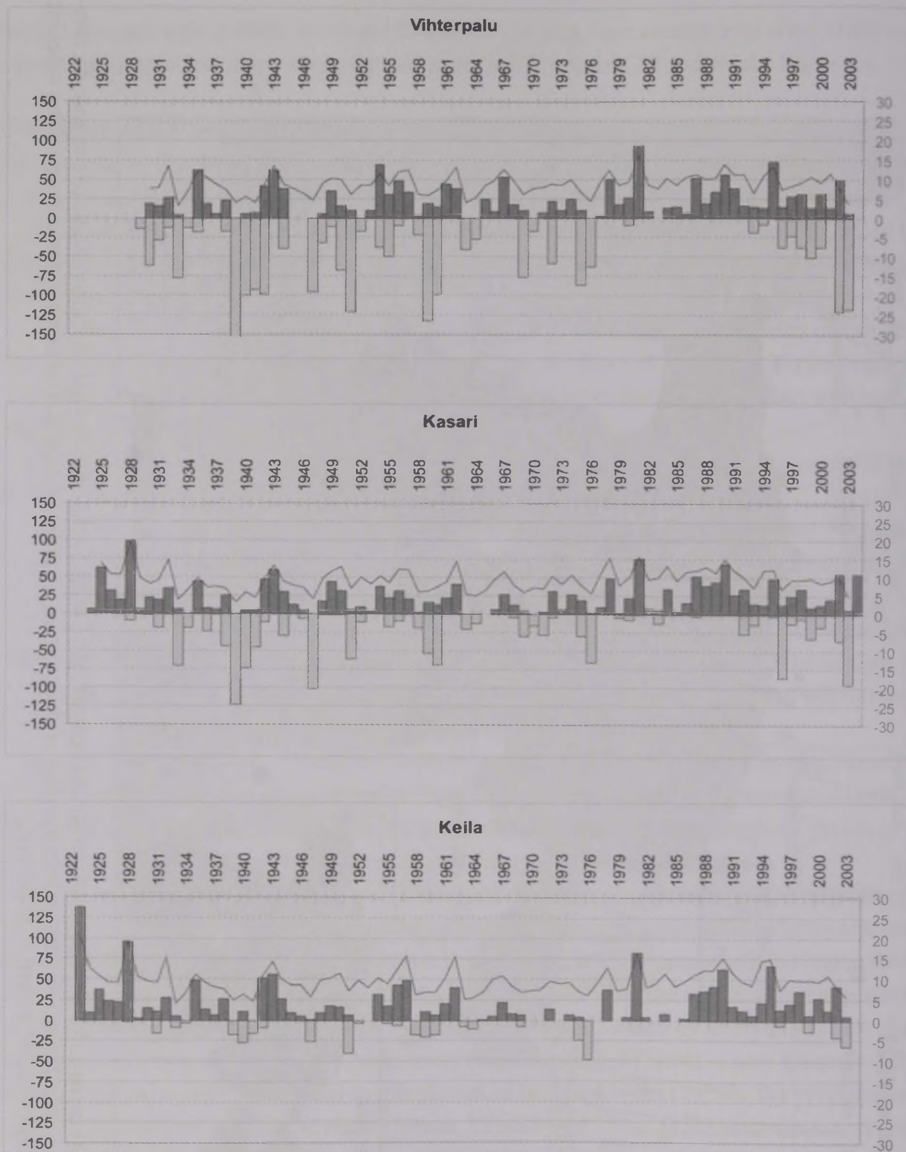
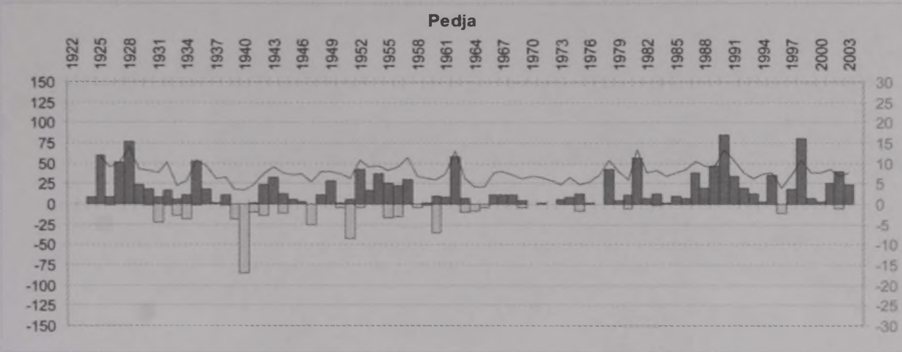
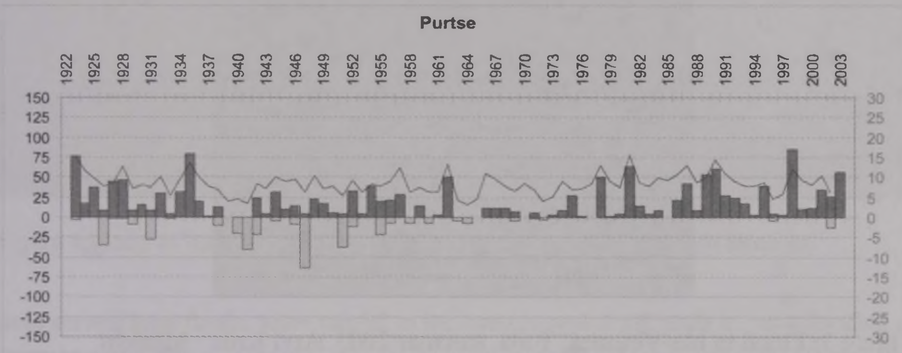
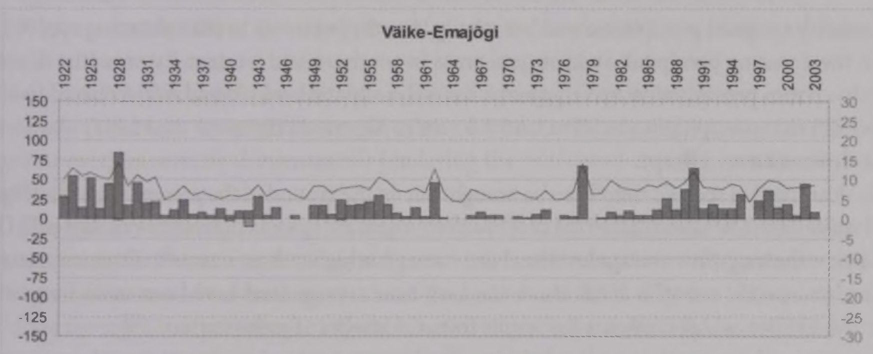


Figure 2: Long-time (1922–2004) variation of specific runoff (constant line, values on the right Y-axes) and number of days when it has been 80% below or 200% above the set limit (bars) is presented (see location of rivers on the map Fig. 1).
A) Rivers in western Estonia: Vihterpalu, Kasari, Keila







B) Rivers in eastern Estonia: Pedja, Purtse, Väike-Emajõgi

Figure 3: Flood in Ida-Virumaa, Toila, summer 2003. Arvi Kriis / Maaleht

the country received precipitation rather evenly. Another extreme occurred in August 2002, when there was no precipitation in several areas in southern and western Estonia (the driest month – 0 mm precipitation in Valga and Vilsandi, a situation which had not occurred in 40 years), 0.3 mm precipitation in Võru, and 0.5 mm in Jõgeva. At the same time heavy showers came down all over Europe.

No clear trend of specific runoff can be brought out on the ground of the presented graphs (Fig. 2). However it can be noted that in the case of rivers in western Estonia the number of days with Q 80% below the long-time average level has been somewhat higher than in eastern Estonian rivers. Days when specific runoff is 200% above the long-time average level have been more frequent since the 1980ies, which confirms the results from the studies of precipitation.

Impacts of drought and floods

Impacts and problems resulting from the extreme meteorological and hydrological conditions in Estonia vary yearly and spatially regardless of the small area.

Resulting from climatic conditions, landscape features and economic conditions, summer floods are causing considerable problems. Despite the fact that Estonia's landscape character-

Figure 4: Flood in Tuukri street, Tallinn, summer 2004. Tiit Blaat / Eesti Ekspress

istics prevent large floods, heavy rainfall in the summer period still tends to cause flooding of extensive areas.

Agriculture as well as other fields of activity in Estonia are vulnerable to floods as:

- approximately 60% of the country's most productive lands are overmoist (gleysols, histosols etc.);
- about 2/3 of the arable land has been drained during the last 40 years;
- over 50% of the drainage systems have deteriorated due to poor maintenance (ditches silted, grown over, incorrectly dimensioned) hindering the outflow of excess rain water from large areas [9].

These factors intensify the negative impact of floods, as has been proved in recent years – the main reason for the serious flooding of agricultural lands in northeastern Estonia in 2003 was the poor condition of the drainage system of the agricultural lands. Negative impacts of flooding during the vegetation period are comparable with drought impacts – strong showers break the soil structure, impair the air and water regime of soil and hinder the activity of aerobic soil bacteria. Floods also impact everyday life in larger settlements – problems occur in sewerage and rainwater collection systems (Fig. 4), water purification, also in mining areas (flooding of mines).

The usage of surface water in Estonia is minor compared to groundwater, thus the changes in the river runoff, e.g. decreased runoff due to drought are not of high importance for the water supply. As total water use has decreased more than 1.5 times per inhabitant since the Soviet era (decrease in agricultural use approx tenfold) [10] due to changes in the economy and more effective water use, the pressure on water resources is not critical and drought does not significantly affect everyday life in settlements. Nevertheless, although the impact of drought is also somewhat mitigated due to the wide occurrence of bogs and moist areas, it has considerable impact on agriculture, since agricultural irrigation systems, mostly originating from the Soviet era, are predominantly in disrepair; the percentage of irrigated agricultural lands is only 0,18% of the total arable land. Owing to sensitive soils (limestone rendzinas) drought damages are more severe in western Estonia.

The ecological conditions of water bodies are also strongly affected by drought – low runoff in rivers impacts their ecological status. Drying up of wells in smaller settlements has also been a problem during drought, e.g. in 2002.

At the EU level a directive is being prepared for managing floods, expected to be adopted in 2006. The main objective of the directive is to assure efficient protection against the negative impacts of floods on human health, the environment and economic activities. The directive determines the compilation of the initial estimation of the appearance of floods, drafting of flood risk maps and flood management plans. In Estonia, activities for raising the awareness of people about floods, their impacts and prevention, began in 2005 [8]. Documents have been drafted for managing the risks of flooding. To mitigate the crisis situations brought on by floods and drought in the future, it is necessary to draw attention to amelioration systems, maintenance of drainage systems, monitoring of the state of water bodies (assure their upkeep and prevent over growth) and building activities in the areas with potential flooding risk.

Conclusions

In Estonia, both drought and floods occur as extreme weather conditions, caused mainly by scarce or heavy precipitation respectively. The occurrence of drought and floods is random and differs significantly over years and throughout the territory due to specific climate conditions.

Global climate change is expected to alter the meteorological and hydrological conditions, including the frequency of extremes. Studies have shown an increase in the occurrence of floods in Estonia in recent decades, and the impacts of floods have thus been more severe.

As the preventive measures to be taken in case of the extremes (drainage, irrigation) are insufficiently developed, the preparedness for drought and flood conditions is low – mainly only monetary measures are taken to relieve the negative impacts. More effective solutions can be found in the maintenance of drainage systems and in developing action programmes for managing extreme conditions.

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Relationships between indicators of landscape pattern and water quality

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Abstract

We investigated the relationship between land use parameters and FRAGSTATS-based landscape metrics — Edge Density (ED), Patch Density (PD), Mean Shape Index (SHAPE_MN), Mean Euclidean Nearest Neighbour Index (ENN_MN), Contagion (CONTAG), Patch Richness Density (PRD), and Shannon's Diversity Index (SHDI) and nutrient/organic-matter based water quality indicators (BOD_7 and COD_{KMnO4} values, Total-N and Total-P concentrations in water) in 24 catchments with various land use patterns in Estonia, using the CORINE Land Cover Map (1:100,000). Multiple regression analysis showed that for BOD_7, Total-N and Total-P, the most important predictor was the proportion of urban areas, but landscape metrics also had a significant relationship with water quality. SHAPE_MN and CONTAG were the most important predictors for COD_{KMnO4}. The knowledge that land use and landscape configuration impact water quality can be used in establishing and implementing water management plans in Europe.

Keywords: Catchments, land use, landscape metrics, water quality

Introduction

Spatial structure of landscapes is a central object of investigation for landscape ecology. This structure is finding its expression in landscape pattern, which integrates both complex conditions of the natural environment (ground sediments, soil, topography, vegetation, local climate) and human-induced changes, first of all land use. The latter is the main mode of human impact. Therefore the attempts to measure different parameters of spatial structure are an essential part of the development of landscape ecology.

Hundreds of landscape metrics have been proposed by various researchers to analyse landscape structure. Most of them are covered by the FRAGSTATS computer program [13]. Since the emergence of FRAGSTATS, the measures and methods incorporated into this software have been very widely used. In relation to material export, different landscape metrics have been performed for the description of landscape structure in catchments: areas of landscape elements and distances of landscape elements from water bodies [16], presence of riparian zones [3; 11] and wetlands [17], and various diversity metrics [5; 10]. The influence of land use on water quality has been investigated

Figure 1: Location of study catchments in Estonia

in Estonia by [8; 13]. According to contemporary research [4] water quality in streams is scale-dependent and varies over time and space. Numerous studies have found landscape structure to be the main factor influencing nutrient and organic matter runoff from watersheds [13; 19; 20]. Several studies have shown stream water quality to be effectively detectable using remote sensing data [6;7]. [9] have found that using only landscape measurements obtained solely from remotely sensed data can explain about 75% of the water quality variability in catchments.

The aim of our study was to ascertain the relationship between the quantitative and qualitative parameters of the spatial structure of landscape and nutrient/organic matter-based water quality indicators in catchments with various land use patterns. We limited ourselves to the possibilities offered by FRAGSTATS and to the existing cartographic and monitoring data.

Material and methods

Water quality data

We used the water quality data from the database of the Estonian Environmental Monitoring Programme database. 57 catchments are included in the Environmental Monitoring Programme. Of these 57 catchments, we could only use 24, because many catchments extended almost all the way to Russia or Latvia. We could also not use more than one subcatchment in each catchment, or else the data points would not have been independent. Of the monitoring programme data, we used BOD_7 and COD_{KMnO4} values, and Total-N and Total-P concentrations in water samples from the closing weirs of the studied rivers (mg l^{-1}). For annual concentrations, we calculated arithmetic means for the years 1996–1998 (the land cover maps were made in this period). However, we presume that the selected catchments present a representative sample of all Estonian catchments.

The disadvantage of these data was their dependence on point pollution sources (towns, factories). However, the relation between the Biological Oxygen Demand (BOD_7) and the Chemical Oxygen Demand (determined based on potassium permanganate; COD_{KMnO4}) helps to distinguish between anthropogenic (mostly point pollution) sources and natural/ semi-natural sources of pollution. In particular, high BOD_7 values indicate the presence of point-pollution sources (urban and industrial areas, settlements), whereas the COD_{KMnO4} value is high in natural areas with a high percentage of swamps, fens and bogs [4]. Therefore the COD_{KMnO4} is closely comparable with the widely used Dissolved Organic Carbon (DOC) value [14].

Land cover data

To determine relationships between landscape metrics and water quality, we used the land cover maps of 24 Estonian catchments (Fig. 1) that were included in the Estonian Environmental Monitoring Programme.

The data used for the calculation of landscape metrics was derived in raster form from the CORINE Land Cover Map of Estonia (1:100 000). The CORINE database allows the use of this method in other parts of Europe. The spatial resolution was 30 m, and landscape metrics were calculated using FRAGSTATS on the original CORINE Land Cover types that are listed in the first column of Table 1.

In order to ascertain the relationships between land use and water quality, we reclassified CORINE land cover types into four general groups: 1) the proportion of natural areas (NA) (forests, grasslands); 2) the proportion of agricultural land use (ALU); 3) the proportion of fens, bogs and mires (FBM); and 4) the proportion of urban land use (ULU) (Table 1). These land use proportions were used in the regression analysis. Mining lands, dump sites and peat bogs were classified as Other and were not used in the analysis.

Landscape metrics

The landscape metrics were analyzed using the computer programme FRAGSTATS [13]. Many of the landscape metrics are correlated with each other. Therefore we performed a correlation analysis and picked those landscape metrics that did not correlate significantly with the others [18]. There was only one exception – patch density, which correlated with edge density, but is very often used. We used the following landscape metrics: 1) Edge Density (ED) - the total length of all edge segments per ha for the landscape under consideration; 2) Patch Density (PD) - the number of patches per unit of area; 3) Mean Shape Index (SHAPE_MN) - patch-level shape index averaged over all patches in the landscape; 4) Mean Euclidean Nearest Neighbour Index (ENN_MN) - a

Table 1: Land use and land cover types in study catchments

CORINE Land Cover Map 1:100,100	*New classification*
Lakes, ponds	Natural areas
Water courses	Natural areas
Non-irrigated arable land	Agricultural land use
Urban lands	Urban land use
Mining lands	Other
Dump site	Other
Inland marshes	Fens, bogs and mires
Bogs	Fens, bogs and mires
Peat bogs	Other
Salt marshes	Fens, bogs and mires
Green urban areas	Urban land use
Sport and leisure facilities	Urban land use
Fruit trees and berry plantations	Agricultural land use
Pastures	Agricultural land use
Coniferous forest	Natural areas
Mixed forest	Natural areas
Natural grassland	Natural areas
Moors and heath land	Natural areas
Sparsely vegetated areas	Natural areas

patch-level distance (m) to the nearest neighbouring patch of the same type, based on the shortest edge-to-edge distance averaged over all patches in the landscape; 5) Contagion (CONTAG) - indicates the aggregation of patches; 6) Patch Richness Density (PRD) - the number of patch types per unit area; and 8) Shannon's Diversity Index (SHDI) - based on information theory, indicates the patch diversity in the landscape. For details and metric formulae see [13].

Statistical analysis

According to the Kolmogorov-Smirnov test for normality, all of the variables under consideration were normally distributed, except for one variable – Total-P. Stepwise multiple regression analysis was used to analyze the dependent variables of water quality, and landscape metrics and land use proportions as independent variables. The probability to enter variables into the stepwise regression model was set at $p < 0.01$, and the probability to remove at $p < 0.05$. For the statistical analysis of data, the computer program STATISTICA 6.0 was used. The level of significance of $\alpha = 0.05$ was accepted in all cases.

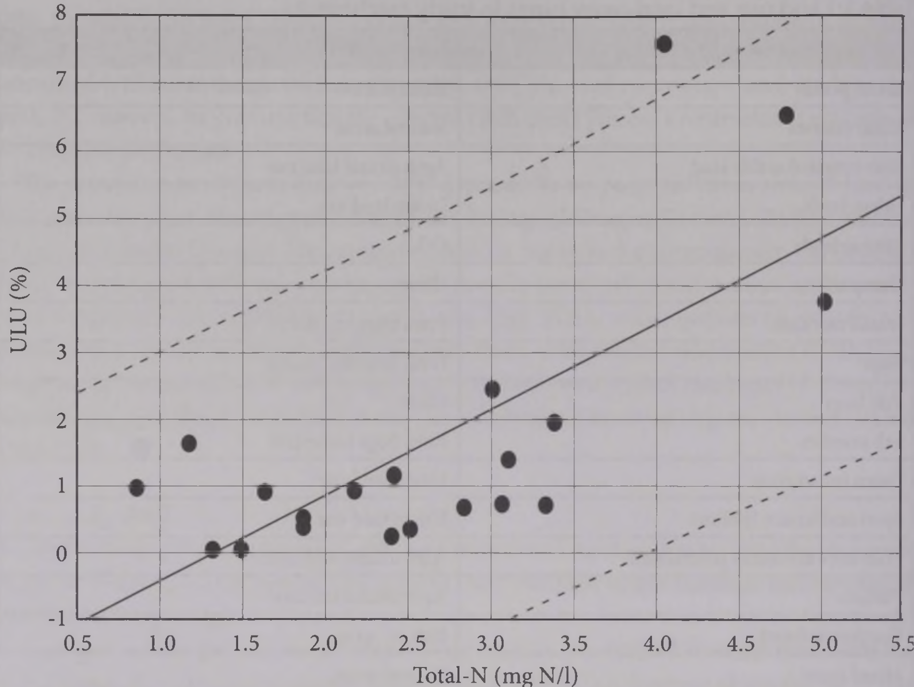

Figure 2: Relationship between ULU and Total-N. The solid line is the linear regression equation. The dashed lines indicate the 95% prediction intervals.

Results and discussion

BOD_7

Regressions of landscape metrics and land use proportions explained up to 82% of the observed variation in BOD_7. ULU and PD were the most important predictors. Catchments with high ULU had higher values of BOD_7. As the PD showed a negative correlation with BOD_7, lower amounts of organic matter are washed out of the catchments with high PD values. The importance of ULU in regression equations shows the role of point pollution sources in BOD_7 values. It seems, however, that landscape complexity also significantly influences BOD_7 values.

COD_{KMnO4}

For COD_{KMnO4}, the most important predictors were SHAPE_MN and CONTAG. Lower amounts of humic and fluvic acids are washed out of the catchments with low SHAPE_MN values and high CONTAG values (fragmented landscape structure). Land use proportions were also important predictors in regression equations for COD_{KMnO4}. ALU, NA and FMB were good predictors, which show that organic matter losses are higher from natural areas, swamps, fens and bogs [4]. Therefore the COD_{KMnO4} values are higher when fens and natural areas account for a high proportion of the catchment's land use, and landscape is fragmented.

Total-N

For Total-N, ULU was the most important predictor explaining up to 50% of the observed variation of Total-N. Although the R^2 is not very high, fig. 2 shows that with increasing ULU values, the Total-N value also increases. The good correlation between Total-N and ULU indicates the insufficient waste water treatment in the catchments [1]. This is a critical problem, especially in catchments that belong to the Gulf of Finland basin. ALU and ED were also a predictors for Total-N – with increasing ED values, the Total-N concentration decreases. Good correlation between ALU, ULU and Total-N refers to the important role of land use in Total-N runoff [2; 8; 18].

Total-P

For Total-P, ULU was the most important predictor, explaining up to 74% of the measured variation. The close correlation between Total-P and ULU points to the problem with phosphorus removal from wastewater originating from industries and towns [15;21]. Fig. 3 shows that Total-P is positively correlated with ULU. The relationship between ULU and Total-P is very close, because Seljajõgi and Pühajõgi catchments have high values of ULU and Total-P. These two have a lot of industries and a high population density, which is the main source of phosphorus. The removal of phosphorus in waste water treatment plants is evidently insufficient. If these two catchments are left out of the analysis, there is no relationship between ULU and Total-P. These analyses were performed with water quality data from the years 1996–1998, but for the year 2003, the value of Total-P in Pühajõgi catchment had decreased almost four times. However, the relationships between Total-P and ULU may lead to the wrong conclusion, because urban areas are impervious, and drainage is frequently routed to waste water treatment plants (which may or may not be in the same basin), and then discharged to local rivers as point sources [1]. Furthermore, [1] found that population density describes water quality better than the % of urban areas.

Conclusions

Land use proved to be the most important predictor for water quality, but landscape structure also had a significant role in predicting the values of water quality in catchments. For BOD_7, Total-P and Total-N, ULU was evidently the most significant predictor, because in catchments that belong to the Gulf of Finland basin, organic matter, nitrogen and phosphorus runoff is strongly influenced by point pollution sources. There are also problems with waste water treatment in many Estonian catchments. In addition to ULU, ALU and ED seemed to play an important role in predicting values of Total-N. For BOD_7, PD was also an important predictor. Catchments with complex landscape configuration have lower organic matter runoff. Lower amounts of humic and fulvic acids are washed out of catchments with complex landscape structures (low CONTAG and high

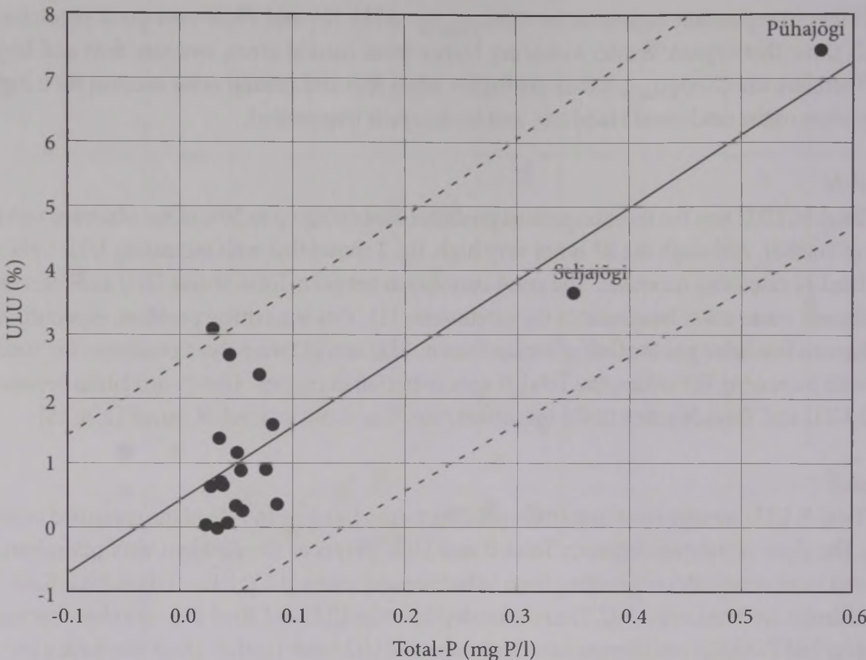

Figure 3: Relationship between ULU and Total-P. The solid line is the linear regression equation. The dashed lines indicate the 95% prediction intervals.

SHAPE_MN). We can conclude that even with the same land use, landscape configuration plays an important role in organic matter and nutrient runoff from catchments.

Although the regression models used in this study can not be used in other catchments, the methods can be applied anywhere in Europe. The CORINE Land Cover Map may be used for landscape metrics calculation.

Acknowledgments

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Application of the ecomorphological monitoring method EcoRivHab with usage of GIS tools

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Abstract

The paper summarizes ecohydrological assessment principles and their application in the monitoring of the river habitat quality according to the new European Water Framework Directive 2000/60/EC. Studied ecohydrological methods are based on a comlex assessment that combines hydrological, hydromorphological, hydrochemical and hydrobiological approaches. For the assessment of the river habitat quality, the EcoRivHab method, which is mainly based on hydromorphological assessment, was chosen. During the field mapping, assessment, and subsequent presentation of the ecomorphological condition of streams, GIS tools were used. As a study area, a small sized waterbasin, the Košínský Brook located in the southern part of Bohemia in the Czech Republic, was chosen. In the selected catchment, an acute need of ecomorphological assessment of the watercourses emerged because of strong eutrophication of the Jordan water reservoir.

Keywords: ecomorphological assessment, hydromorphology, riverbed, riparian belt, flood plain, the Košínský Brook, the Jordan water reservoir

Introduction

Humans already appropriate over half of the world's accessible surface water and this is projected to increase to an astounding 70 % by 2025. The main aim of the new European Water Framework Directive 2000/60/EC [3] is to improve the ecohydrological status of our surface water bodies. One of the most striking human landscape changes can be seen in the case of stream modification, which has changed significantly the runoff regime, fluvial-morphological processes, hydrochemical and hydrobiological conditions, but has also restricted the aesthetic functions of river habitat. The main goal of our research was the assessment of ecomorphological river habitat quality in the selected water basin. Results of the assessment should help to localize stream reaches in bad ecological condition but also to find areas where the greatest amount of nutrients enters the water environment.

Methods

Ecohydrological methods are complex assessment principles that integrate hydrological, biological and landscape approaches. The ecological state of a river ecosystem is usually evaluated on the basis of hydromorphological features of the riverbed, flow regime and groundwater connectivity, physical-chemical parameters of water quality, biological water quality assessment, character of the riparian belt, and human impact on the flood plain ecosystem. These parameters form the ecological integrity of a water ecosystem, which is the basis for integrated management and protection of water ecosystems. Although ecological integrity is and must remain a holistic concept, a number of key components of the assessment procedure can be investigated and evaluated [5].

The basic precondition is the creation of a healthy river landscape form, the so-called reference state. The reference state is defined as the state without human influences that significantly change the natural characteristic of the river habitat. In general two main classification systems can be applied. The first possibility is a verbal description and discussion of the evaluated water body; the second is based on a score system and its subsequent comparison with standard values.

Many methods are available to assess aquatic ecosystems. The initial material investigated was the Water Framework Directive (EC/2000/60) [3], which defines universal approaches for the assessment of the ecological condition of water bodies. The ecological state and evaluation parameters of the river habitat is described in the WFD only in a general way, as it is problematic to specify and quantify the properties of water bodies in different European ecoregions. Countrywide typologies, monitoring programs and many research projects are applied.

Secondly, the following foreign methods were studied: German LAWA-Field and Overview Survey [9,10], British River Habitat Survey (RHS) [14], the American assessment system HABSCORE (USEPA Rapid Bioassessment Protocols) [1], the Canadian system Channel Assessment Procedure Guidebook [13]. Thirdly, the following two Czech assessment systems were studied: Multicriterial Analysis of Streams and Survey of Dynamics and Protection of Natural Ecosystems of Streams [15], and Predictive Biological Assessment System PERLA [16].

As a result of our research, we found that the following methods: LAWA, RHS, HABSCORE and the Ecomorphological River Habitat Monitoring (EcoRivHab) [11], were the best suited. In the next phases, at least two of these will be used in each catchment.

Use of the geographic information systems (GIS) represents a necessary tool in mapping, assessment, and subsequent presentation of the ecohydrological condition of streams. Digital processing of thematic layers of the watercourses and riparian belt represents a basis for ecomorphological monitoring. The assessment is based on field mapping above all, during which features of individual parameters are recorded in mapping form using the GIS tools, including their necessary accurate localization. The usage of handheld devices equipped with mobile GIS applications like e.g. ESRI ArcPad is also efficient, allowing editing of geo-databases in the ArcGIS format, as well as accurate localization of elements in the field directly.

The ecomorphological river habitat assessment

EcoRivHab method is being tested as part of the research project «cohydrological monitoring

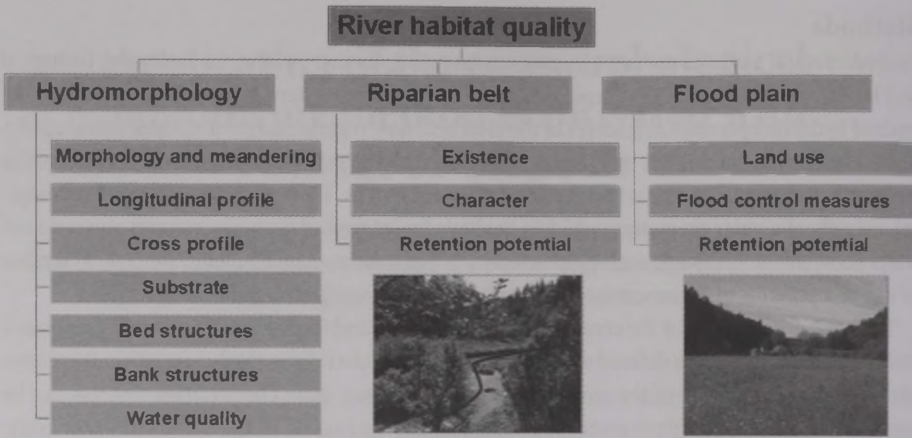

Figure 1: Scheme of the river habitat quality assessment according to EcoRivHab method

of river habitat quality in context with WFD». This method is based on the previously formulated ecomorphological monitoring of streams [11,12], which was verified and used during the assessment of selected water bodies in the Landscape Protected Area of Křivoklátsko. This assessment system has five grades, and is compatible with the classes defined in WFD and in ČSN EN 14614 [4]. The EcoRivHab method is an instrument to assess the river habitat in open countryside as well as in urban areas. It is mainly based on field mapping but recommends geo-processing of available maps, digital aerial photographs and available data from the hydrological ecological information system HEIS or other materials from water basin agencies.

The assessment of the hydromorphological status is based on the definition of the potential reference status. Mapping is done in reaches of homogenous or heterogeneous length depending on the catchment size and channel width. With small catchments ($A < 100$ km^2), it is suitable to use reaches of constant length (100 or 200 m). With larger basins ($A > 100$ km^2) it is suitable to perform the mapping in reaches of variable length (200–1000 m). The water ecosystem is understood as a territory, which is formed by individual, mutually interconnected zones: riverbed, riparian belt and flood plain (Fig. 1). Assessments of the riverbank features, riparian belt and flood plain are carried out separately during the mapping, but the final assessment is calculated jointly for both river banks. Hydromorphological parameters are classified by a score system $<1; 5>$. Field survey investigates 32 single features, that can be aggregated to 12 main categories (morphology and meandering of the channel, longitudinal profile, cross profile, bed structures (substrate), bank structures, basic hydrochemical and hydrobiological parameters of surface water quality, existence and character and retention potential of the riparian belt, land-use, flood control measures and retention potential of the flood plain.

Data sources

Aerial images on a scale of 1:5,000 (source: Institute of Landscape Ecology [ILE] of the Academy of Sciences in České Budějovice [ASČB]) and digital layers ZABAGED 1:10,000 (source: ILE, ASČB) were used as the base materials for ecomorphological mapping. In the course of mapping, records of selected natural and anthropogenic parameters were taken (e.g. natural and artificial steps, modifications of the riverbed, and potential retention areas spaces in the riparian zone). Point assessment of individual parameters for all the watercourse reaches observed were recorded in the ecomorphological mapping forms, and subsequently processed and evaluated statistically.

Thematic GIS layers were further used to assess land use in the riparian zone, and to determine features of the ecological potential of soils [7]. Assessment of river network modification and the proportion of drained areas was performed based on thematic mapping materials 1:10,000 of the watercourse administrator (Agricultural Water Management Administration [AWSDA], Tábor).

Application of the EcoRivHab method in the study area

The river basin of Košínský potok (Košínský Brook), found in southern Bohemia (Fig. 1), was chosen as the study area. It is a small sized watercourse with the catchment's area of 80 km^2. The brook rises in a hilly country area, approximately 20 km from the town of Tábor (located 80 km south of the capital city of Prague). On the main stream near the town of Tábor, the water reservoir Jordán is found. Below the dam of Jordán, the watercourse flowing off is called Tismenický potok (the Tismenický Brook), and it joins the Lužnice River from the right, at the 40th river kilometre [2].

Košínský Brook is the most significant water source for the Jordán reservoir, which represents the oldest valley reservoir in Central Europe. The reservoir is found at the north edge of the historical town of Tábor, it was built already in 1492. The reservoir originally fulfilled several functions; it primarily provided a drinking water supply, it was also used for fire fighting, and the town spa was built on its bank. Later, in the 16th century, together with the flourishing of the pond building, the reservoir started to be used to breed carp and other productive fish. Several facilities were created near Mal Jordán, a small settling reservoir before Jordán; these facilities provide an opportunity for sports fishing, the town spa was reorganized into a pike hatchery. At present, an effort has been made to use the reservoir for recreational purposes as well, for example, for bathing and camping.

However, satisfactory and safe recreational utilization of the reservoir in warm summer months is hindered by considerable eutrofication connected with the growth of algae and cyanophytes, worsening subsequently the oxygen conditions in the reservoir and leading to the production of toxic substances. This condition is caused by the excessive supply of nutrients from the river basin area to the reservoir; this concerns especially phosphorus and nitrogen that are brought into watercourses from agricultural areas and from municipal wastewaters [6, 8]. For this reason, an acute need for the ecomorphological assessment of the watercourses emerged. The purpose

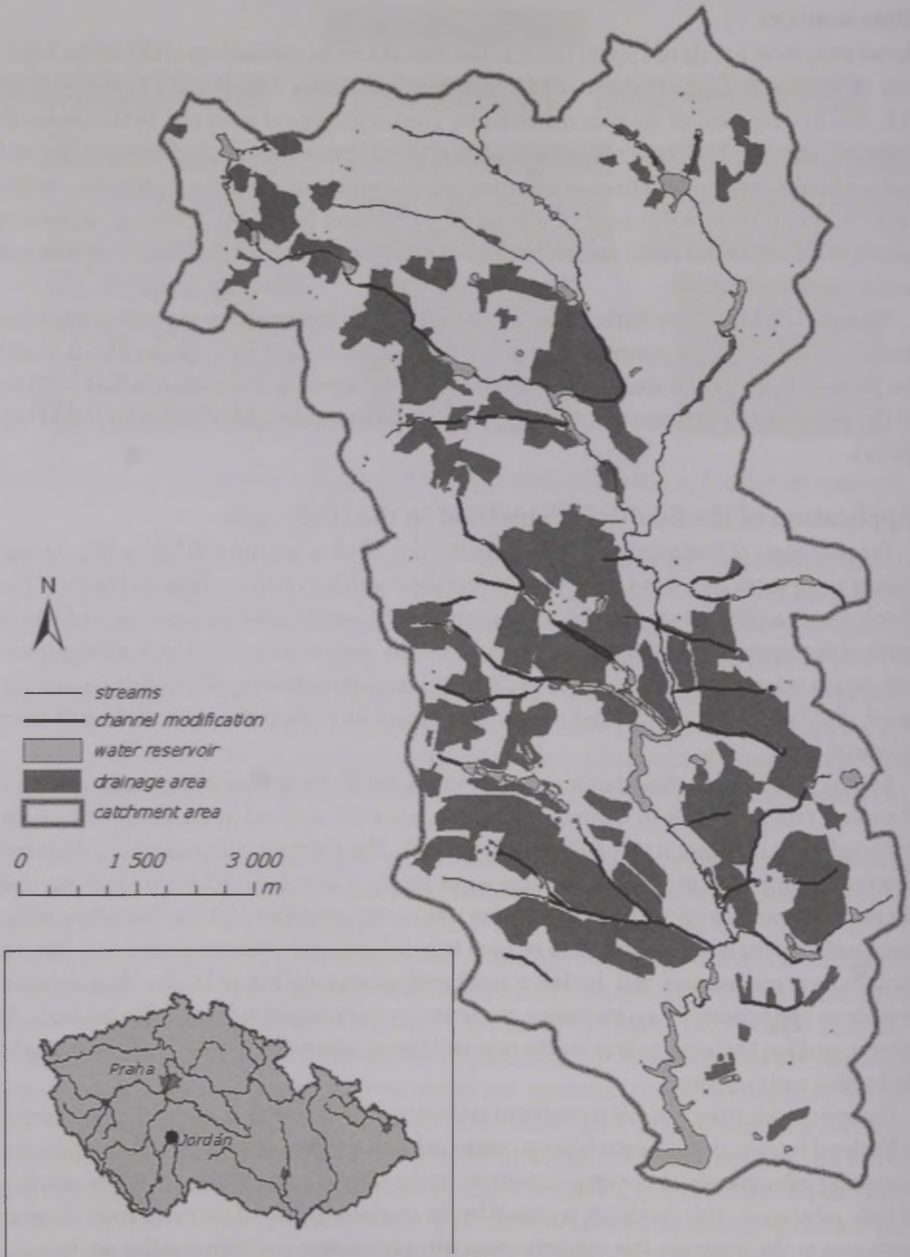

Figure 2: Drained areas and modified watercourses in the Košínský Brook basin

was represented by the need of accurate localization of the watercourse reaches where the greatest amount of nutrients enter the water environment, and where an accelerated transport of the nutrients into the reservoir occurs.

Land use of the riparian zone or possibly of the whole flood plain represents a significant factor that affects the overall ecomorphological status. From this point of view, the study area can be divided in two parts the northern woody and the southern agricultural part. In the southern part of the river basin, utilized intensively for agricultural purposes, short watercourses prevail, into which the ameliorative drains are discharged. These watercourses are straightened, deepened, with banks and bed fortification; riparian strips are missing entirely or show a non-suitable vegetation structure. Within the framework of the assessment, such watercourses were marked as the B group; their total length is 29.6 km. Woods largely cover the northern part of the river basin; basic hydromorphological parameters of the riverbed show a natural or near natural status; the riparian strips are developed in sufficient width and have suitable vegetation composition. Watercourses in this part of the river basin, together with the whole length of the main stream of Košínský Brook, were marked as the A group; their total length is 35.8 km.

Straightening of the watercourses and drainage of areas

The Košínský Brook basin has been used intensely for agricultural purposes; a total of 72% of the river basin has been cultivated; out of that, 78% represents arable land. Because of the need to increase the agricultural land area, to improve its quality and achieve a simpler and more efficient manner of cultivation, large areas were drained and riverbeds were straightened in the course of the 2nd half of the 20th century. Out of the total area, more than 23% was drained, 44% of the hydrographic network was modified, and 6% was canalized. 50% of the length of all the watercourses studied was thus modified. The majority of drained lands and modified riverbeds are found in the southern part of the river basin (Fig. 2).

Hydromorphology of the riverbed

Due to extensive hydro-amelioration measures, hydromorphological characteristics of the riverbeds were changed. Their current ecomorphological status was assessed comprehensively within the riverbed zone investigation. The ecomorphological degree (ED) I. and also II. (prevailing natural structures or near natural structures) was assigned to 56% of the total length of all segments; and the ED IV. and V. (reaches with strong up to very strong anthropogenic impact) was assigned to 36% of the total length. More than 5% of the reaches' length is canalized.

Based on these resulting values, the riverbed zone can be described as a zone with significant anthropogenic impact. However, there are large differences between individual watercourses, and therefore the watercourse groups A and B were assessed separately. Riverbeds of group A can be described as those with intermediate anthropogenic impact, while in group B, the riverbeds show strong anthropogenic impact (Fig. 3, 4) shows the ED development in the longitudinal profile of the Košínský Brook, from the spring to the mouth.

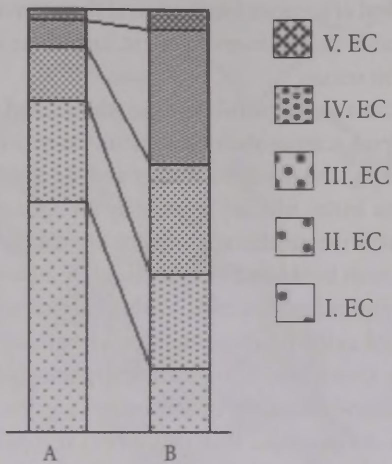

Figure 3 Assessment of the ecomorphological status of the riverbed zone in the Košínský Brook basin; A and B watercourse groups are assessed separately.

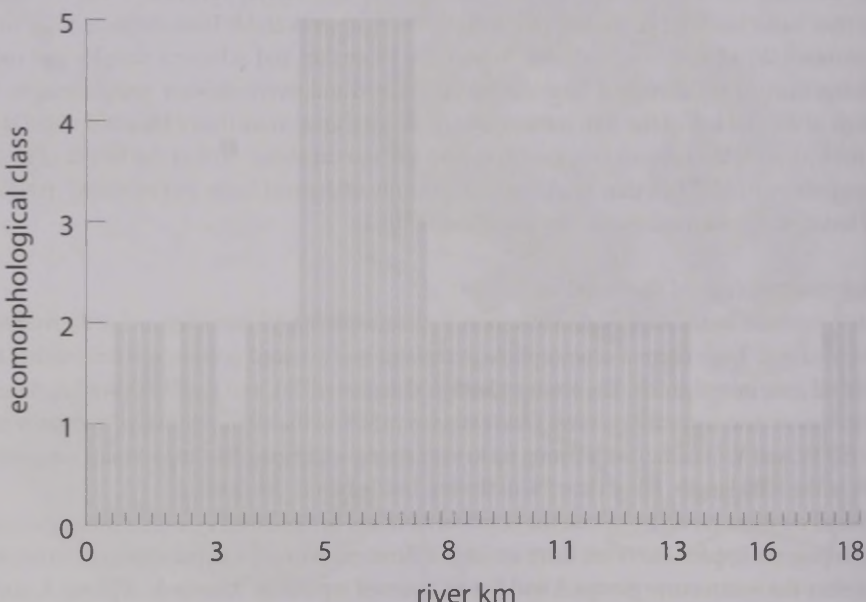

Figure 4 Development of the ecomorphological status of the riverbed in the longitudinal profile of the Košínský Brook.

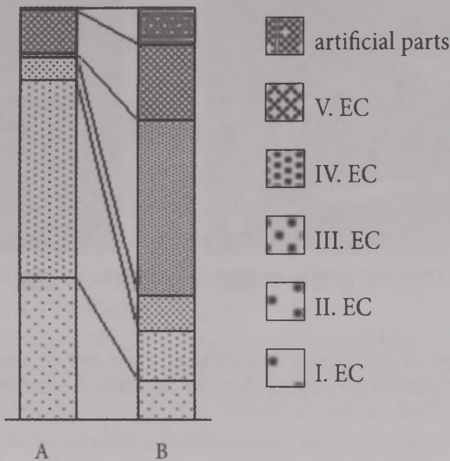

Figure 5: Assessment of the ecomorphological status of the riparian zone in the Košínský Brook basin; A and B watercourse groups are assessed separately.

Riparian belt

Together with modifications of the watercourse riverbeds, the riparian belt was modified by man too. As a rule, such modification meant their narrowing (note: the minimum size of 10 m from the left and right bank). Natural vegetation was removed in the course of construction, and was replaced subsequently most often with self-sowing vegetation. In other places, such areas were sown with grass or possibly planted with vegetation of sometimes natural, sometimes non-natural species composition. The nature of the riparian belt also depends on land use in the surroundings of the watercourses.

In assessment of the whole river basin, ED I. and II. was assigned to 71% of the studied river network; ED IV. and V. was assigned to 8% of the total length. Based on these results, the riparian belt can be described as a zone with moderate anthropogenic impact, while a marked difference between the A and B watercourse groups studied was shown. In group A, the riparian strips show largely a natural or near natural status; in group B, they show an intermediate degree of anthropogenic alteration (Fig. 5).

The flood plain

A land use layer with 36 categories was available as the input base material to assess the flood plain condition; these categories were further divided into five basic groups according to ecological stability of individual land use types. The alluvial plain does not have any strictly marked geomorphologic boundary. The zone was assessed on the basis of the land use in two strips of

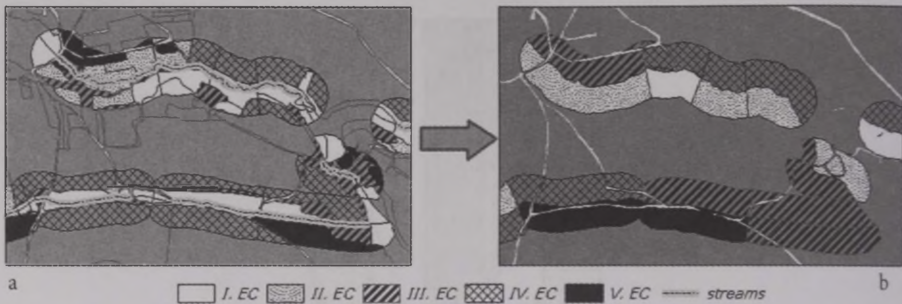

Figure 6: Example of ecological stability assessment of the flood plain (100 m zone), a) continuous assessment; b) assessment in delimited reaches

different width in the zones extending 100 m and the 500 m from the watercourse banks. In the 100 m strip, the delimited zone was furthermore divided into parts showing identical length with the watercourse reaches delimited during field mapping. Within the delimited segments (dimensions: mapped reach length * 100 m), and based on percentage representation of areas of various land use categories, the resulting value of the ecomorphological degree was calculated separately for the right and left banks, and the ecological stability value of the given segment was subsequently determined (Fig. 6).

Table 1: Percentage representation of degrees of ecological stability based on land use in the 100 m zone.

(%)	A	B	A+B
I.EC	54	15	36
II.EC	24	22	23
III.EC	13	27	19
IV.EC	6	32	18
V.EC	3	5	4

In the 500 m band, ED I. and II. was assigned to 42% of the total area, and ED IV. and V. was assigned to 52% of the area. Areas with anthropogenic impact are thus more frequently represented in this strip than are near natural areas. In comparison, in the 100 m strip along the watercourses, 61% of the total area was described as near natural (ED I. and II.), and 33% was identified as an area with considerable anthropogenic impact (ED IV. and V.). Upon comparison of the assessments of both strips, it follows that, in the 100 m strip, or the area closer to the watercourse, there are relatively more areas of ecologically stable nature (ED I. and II.) than of unstable nature

(ED IV. and V.) (Tab. 1). This is due to the presence of a r vegetation in the 100 m strip, to which agricultural or urbanized areas are adjoined assessment in the 500 m strip.

The river basin zone

The nature of land use expresses in principle the extent of anthropogenic impact in the landscape and the ecological stability of the areas. Out of the total catchment area, almost 50% of the area is used as arable land. Woods occupy 26.5%, meadows, pastures, and parks occupy almost 13%, and other areas occupy 7% of the total river basin area. It follows from this characterization that approximately one half of all areas are very unstable ecologically (arable land), and only slightly less than 40% can be described as ecologically stable areas.

All the lands with a high value of specific land loss are used as arable land. The main cause lies in the vegetation cover factor and the plot size, length of the hillside, and the slope factor.

The overall ecological potential of the soils was calculated on the basis of seven different characteristics (buffering; resistance against contamination and intoxication; amount, quality, and reserve of humus; resistance against wind and water erosion; water regime of the soils; and structure of the soils) [7]. The overall potential is high in 56% of the river basin, and it is average and low in 44% of the river basin area, while arable soils in the southern part of the river basin are concerned predominantly.

Summary of the ecomorphological assessment

In the case of the Košínský Brook basin, the main purpose of the ecomorphological assessment of the watercourses consisted of delimiting the areasof poor ecohydrological status and, at the same time, in localizing the main source areas of excessive input of nutrients, in order to reduce excessive eutrofication of the Jordán water reservoir. The following parameters were chosen to delimit the areas:

- Erosion exposure of the areas choice of lands with potential erosion risk higher than 4 t/ha;
- Land use of the flood plain in the 100 m strip along the watercourses ecologically unstable areas, without sufficient buffering potential were chosen;
- Modified watercourses segments of modified watercourses assessed in the riverbed zone and in the riparian belt of ecomorphological degree IV. and V. Water flows faster in modified riverbeds, providing limited possibilities for nutrient retention;
- Point and non-point sources of nitrogen and phosphorus delimitation within a sub-basin;
- Ecological potential of the soils soils with low ecological potential were chosen.

Based on the parameters above, reaches in a poor ecohydrological condition were predicted in the river basin (Fig. 7).

Watercourses in good ecohydrological condition prevail in the northern part of the river basin - with a few exceptions, only ED I. or II. was assigned to the reaches in the riverbed zone and in the riparian belt. The majority of this area is forested and no marked anthropogenic interventions were made here. The riverbeds show a natural or a near natural status; the riparian belt

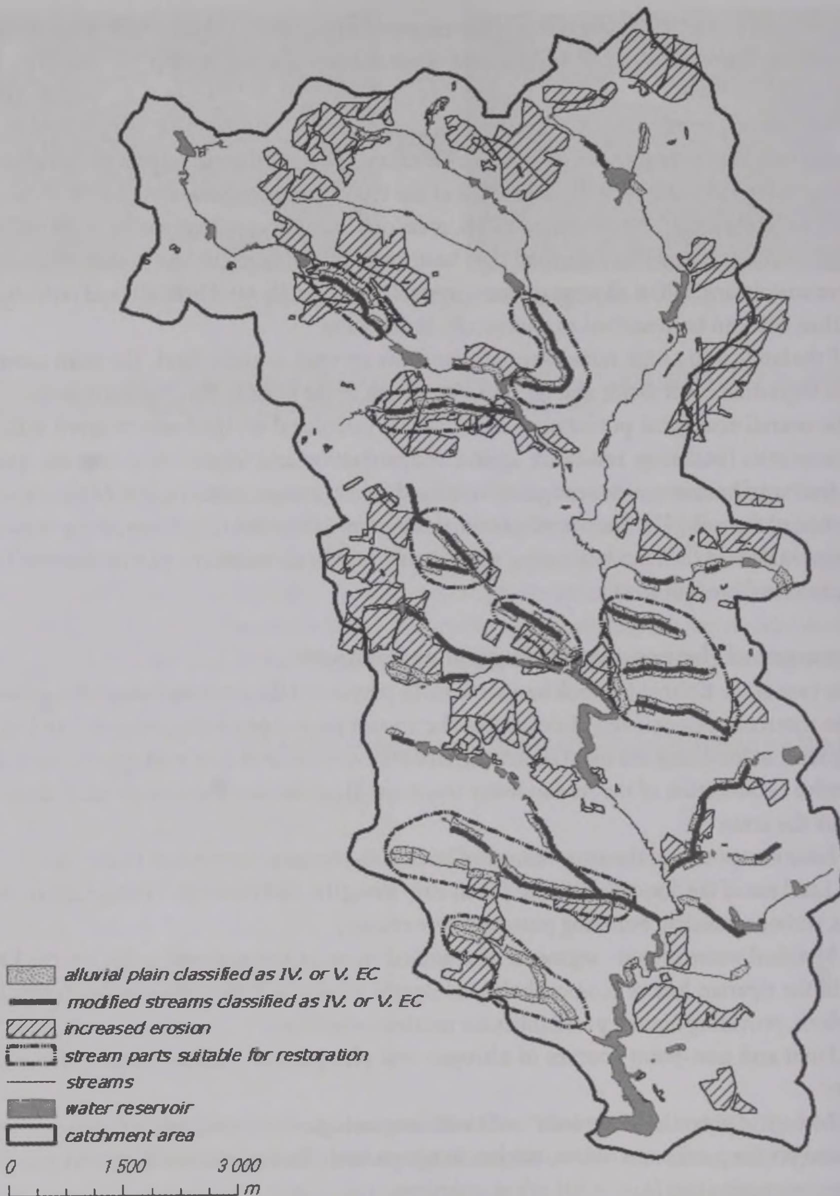

Figure 7 Delimiting of areas found to be in poor ecohydrological condition in the Košínský Brook basin

shows sufficient width and has natural vegetation. On the contrary, the southern part of the territory studied presents an entirely different picture. Intensive agricultural land use is present in the area, and the area has been modified considerably by past anthropogenic interventions. The majority of the area is formed by large plots of arable land without permanent stable vegetation cover, which are liable to erosion. In order to achieve more efficient land use, the majority of the agricultural areas were drained in the past. The riverbeds were straightened, deepened, and fortified against erosion; the longitudinal gradient of the watercourse was increased, and thus outflow from the area was accelerated. The original natural riparian belt was reduced below 10 m or removed entirely in some places, and was replaced spontaneously by self-sowing vegetation. In some segments, arable land even reaches the edge of the riverbed. Parts of the riverbeds were fully canalised. Within the framework of ecomorphological monitoring, ED III. V. was assigned to these watercourses. In the southern part of the river basin, the natural status was preserved only in the alluvial plain of the Košínský Brook mainstream, near the water reservoir of Mal Jordán. The riverbed shows a natural status here, the riparian strips are fully developed and have a natural species composition.

Conclusions

Methods of ecohydrological monitoring allow the performance of complex assessment of watercourse condition. Their more extensive application in practice is not related only to the need to implement the requirements of the European WFD in water management practice. The outputs they provide can be applied in designing specific revitalization measures in the river basins of interest. Assessment of the river habitat quality based on quantification of hydromorphological, hydrochemical, and hydrobiological features allows, at the same time, the performance of mutual comparisons of ecohydrological conditions not only in the given river basin but also within a broader area of hydrological ecoregions. The results obtained contribute, without a doubt, to integrated protection of water sources and their sustainable development in the future.

It would be suitable to implement revitalization measures in the predicted source areas of excessive input of nutrients within the Košínský Brook basin. This concerns especially the renewal of the functionality of the riparian zone, and also application of biotechnical adjustments of the riverbeds of the watercourse.

Acknowledgments

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Water and sediment quality in fluvial lakes – the central Elbe River

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Abstract

From the year 2000, the environmental state and the impact of human activities on fluvial lakes in the central part of the Czech section of the Elbe River is evaluated. For that purpose, three oxbow lakes were chosen: Lake Labiště pod Opočínkem (east of Pardubice), Lake Doleháj (near Kolín), and Lake Obříství (near Mělník). All of them are situated within an area with a well-developed chemical industry and the nearby lowlands are one of the most intensively farmed areas of the Czech Republic. In spite of their identical origin during river canalization, major differences were found. E.g. very low oxygen saturation in Opočínek (mean saturation 46 %) was determined. Nutrient concentrations and their seasonal dynamics (nitrites, nitrates, ammoniated ions, and phosphates) differed in each lake as well. The lowest concentrations of heavy metals (Ag, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) in sediments were found in Doleháj. In samples from Obříství after a big flood in September 2002, the Index of Geoaccumulation increased only for Pb and decreased for Hg. This result indicated that the pollution has probably not occurred during such floods.

Keywords: Oxbow lake, Elbe, flood, water quality, pollution, plankton, heavy metal, sediment

Introduction

Research on lakes has been one of the basic avenues of research in the geography department of Charles University for nearly one hundred years [15,16,17,18,21,22,33]. In the 1960s old river arms became a focus of interest, as they had not yet been much explored, but were seen to be significant from an ecological point of view [7,12,13,24]. This paper presents results of comprehensive limnological research on three former meanders of the Elbe River situated between the towns of Pardubice and Mělník in the central part of the Czech section of the Elbe River, which were investigated in the years 2000 to 2002. The lakes were selected because they are situated within areas with well-developed industry and agriculture. During this study, the morphological characteristics of the lakes, their hydrological regimes, the physical and chemical properties of the water column, their hydro-biology, and the heavy metal contents in their sediments were assessed. As research was carried out with identical techniques, simultaneous sampling, and the same sample analyses, the obtained data were fully comparable, and so it was possible to assess the ecological conditions as well as the impact of human activity on the individual lakes.

Methods

Study sites

The first of the selected fluvial lakes – Labiště pod Opočínkem – is situated several kilometres northwest of the town of Pardubice. It originated, as did the two other lakes, from the regulation of the river and is situated very close to it. Its separation from the river is dated as complete in 1913 [19]. At present the lake communicates with the water stream at high river stages by means of a culvert.

The second lake, called Doleháj, is situated northwest of the town of Kolín [4].This lake is the oldest one, as the Elbe River had already been rectified there during the years 1854 to 1855 [35]. It is located at the greatest distance from the present riverbed, and is connected with the river only by a very long inlet channel with low discharge.

The third oxbow lake examined – Obříství [32] – is located c. 5 kilometres south of the town of Mělník, about 6 or 7 kilometres upstream of the junction with the Moldau River, and came into existence in the second decade of the 20th Century, as did Labiště [29]. The Černavka stream flows into the lake, and there is substantial exchange of water with the river, as there is a concrete penstock from which at normal water stages water flows into the Elbe River.

Measurements

At each lake a gauge was installed at the beginning of the hydrological year 2000 and level readings were taken at least biweekly. The depth of the lakes was measured with an echo sounder; for the elaboration of the database and thematic maps, Arc View and Map Info Professional were used.

Physical water quality was measured four times during the course of the hydrological year 2000/2001. Temperature, conductivity, and pH were measured directly in the lakes and were also surveyed during the sampling of the water for chemical analysis. The pH values were measured with a potentiometer using one combined electrode.

Water transparency was measured by means of a Secchi disk. Water colour was assessed in accordance with the Forell-Ule scale, i.e. a comparison of the water colour over the Secchi desk at half of the transparency depth with some obscured standard colours.

Water quality was assessed seven times in the hydrological year 2000/2001. Samples were taken a few centimetres below the water surface and analysed by the application of titration (oxygen saturation, BOD_5, COD_{Mn}, total alkalinity, water hardness, calcium, chlorides) and colorimetric methods (iron, manganese, ammonium, nitrites, nitrates, ortho-phosphates) [10,11].

Hydrobiological analyses were carried out three times during the vegetation season 2001 according to the method of Hrbáček et al., 1985 and Sládeček et al., 1981. Plankton net (100μm mesh size) was used for zooplankton analyses. Total values of phosphorus (using perchloric acid) and chlorophyll a were assessed by spectrometric measurements according to ČSN EN 1189 and ČSN ISO 10260. Analysis of zooplankton sizing was also performed using photos of samples, so that the size of the monitored organisms was measured with the scale that was photographed at the same magnification level [1,25].

Sediment was sampled for the first time in November 2001. In September 2002 samples were taken again in the Obříství locality after the 'century flooding' of the Elbe, which occurred in this month. A column of settled material (30 – 50 cm) was obtained by means of a plastic tube, divided according to its depth into two or three parts (one part 15 cm), which were then analysed separately. The samples were first exposed to a sedimentation test and sieve analysis [38].

The content of silver, cadmium, copper, chromium, lead and zinc in the non-silicate fraction were determined by applying the FAAS method. For the analysis of the fine-grained fraction, extracts of 20-µm mixture of nitric and hydrochloric acids were used. [9,37]. Mercury concentrations were tested from solid samples with an AMA – 254 instrument. The evaluation of sediment pollution was carried out by the Index of Geoaccumulation [26].

Results

Morphometrical characteristics and hydrological regime of the lakes

The maximum depth (2.7 m) was recorded in Doleháj, which has an area of 77 500 m^2 (Table 1). Obříství was the lake with the smallest depth but the largest area and lake basin volume, while Labiště pod Opočínkem is the smallest water body examined [4,19,32]. The results indicated that the Elbe River had not any decisive effect on the water levels of the oxbow lakes [5].

Table 1: Morphometric characteristics of the investigated lakes

Parameter	Labiště pod Opočínkem	Doleháj	Obříství
Total area (m^2)	17850	77500	112820
Perimeter (m)	1019	1725	4014
Max. depth (m)	2.5	2.7	1.6
Mean depth (m)	0.9	1.1	1.2

Physical and chemical parameters of water

The temperature data showed significant dynamics caused by the extremely shallow depth of the lakes (Table 2). For the same reason, no temperature stratification in any dead channel was registered. In all lakes, low values of water transparency were registered (Table 2), corresponding with the mesotrophic or nearly eutrophic character of the lakes [24]. Minimal transparency was recorded during the vegetation season, related to plankton growth (33 cm in Doleháj in June). Practically two times higher values of conductivity were recorded in Obříství, and these varied between 581 and 1236 µS/cm (Table 2).

Table 2: Physical and chemical parameters of the water column – hydrological year 2000/2001

Parameter	Labiště pod Opočínkem		Doleháj		Obříství	
	MV	STD	MV	STD	MV	STD
Temperature [°C]	8.8	4.9	10.7	7.1	9.0	7.3
Conductivity [μS/cm]	395	64	494	74	854	291
Transparency [cm]	62	19	39	4	63	16
Water colour	Yellow-brown		Brown-yellow		Brown-yellow	
pH	8.4	0.6	8.9	0.7	8.5	0.4
Oxygen saturation [%]	46	32	104	36	105	55
BOD_5 [mg/L]	17.7	12.4	9.9	1.9	6.7	5.2
COD_{Mn} [mg/L]	20.1	4.5	24.9	7.66	14.0	4.4
Total alkalinity 4,5 [mmol/L]	4.11	0.69	1.98	0.43	4.20	1.40
Water hardness [mmol/L]	2.31	0.40	2.36	0.26	5.30	2.60
Calcium [mg/L]	78	19	62	10	150	76
Chlorides [mg/L]	17	3	37	4	73	33
Iron [mg/L]	0.09	0.05	0.05	0.02	0.04	0.03
Manganese [mg/L]	0.23	0.11	0.16	0.08	0.10	0.12
Ammonium-N [mg/L]	0.59	0.27	1.20	0.68	0.51	0.32
Nitrite-N [mg/L]	0.01	0.00	0.01	0.00	0.11	0.09
Nitrate-N [mg/L]	0.87	0.12	2.60	1.62	8.50	4.3
Dissolved inorganic N [mg/L]	1.47	0.25	3.88	1.61	9.10	4.2
Phosphate-P [mg/L]	0.41	0.17	0.02	0.02	0.13	0.08
Total phosphorus [mg/L]	0.55	0.11	0.11	0.02	0.22	0.09
Chlorophyll a [mg/L]	83	13	127	1.78	143	122

Transparency, water colour = 4 measurements; temperature, conductivity, pH, oxygen saturation, BOD_5, COD_{Mn}, total alkalinity $_{4,5}$, water hardness, calcium, chlorides, iron, manganese, ammonium-N, nitrite-N, nitrate-N, phosphate-P = 7 measurements; total phosphorus, chlorophyll a = 3 measurements; MV = mean value; STD = standard deviation

Lake water was slightly alkaline in all the lakes examined (Table 2), which was probably due to the reduction of free carbon dioxide by autotrophs [24] during the vegetation season.

In the Obříství and Doleháj lakes, the oxygen saturation of the lake water increased during the course of the vegetation season probably due to the activity of photosynthetic algae and anabaenas [8]. The highest values were found in Obříství in July (203 %) and in Doleháj in April (153 %). In the autumn, oxygen was exhausted by the degradation of organic matter. In contrast, in Labiště pod Opočínkem, an even higher content of biologically degradable matter probably caused the low oxygen saturation of the lake water even during the summer season (in June only 27 %) (Figures 1, 2).

In all the lakes, elevated contents of organic substances were recorded. Higher values of BOD_5 and COD_{Mn} were achieved during the vegetation season, e.g. in Doleháj the highest values of BOD_5 were reached in April (11.6 mg/L), in Obříství in July (17.2 mg/L) and in Labiště pod Opočínkem in September (45.7 mg/L). This situation may correspond to the breakdown and bloom of phytoplankton (Figure 2) [24].

Nutrient concentrations differed substantially between the lakes. The highest concentrations of nitrate nitrogen were detected in Obříství in April (15.02 mg/L). On the other hand, a maximum of ammonium nitrogen was registered in Doleháj in November (2.67 mg/L). The deserted oxbow Labiště pod Opočínkem was, in contrast, characterized by the highest content of phosphate phosphorus in November (0.70 mg/L) (Table 3). These results were probably caused by different types of water contamination resulting from human activity in the different localities, such as the character of fertilizers used in fields nearby, pollution with sewage, etc. Doleháj Lake was characterized by a drop in dissolved inorganic nitrogen, with a minimum of 1.29 mg/L, and phosphate phosphorus concentrations during the summer season, when values of phosphate phosphorus were just at the limits of measurability and did not increase until the end of the monitoring period. A drop

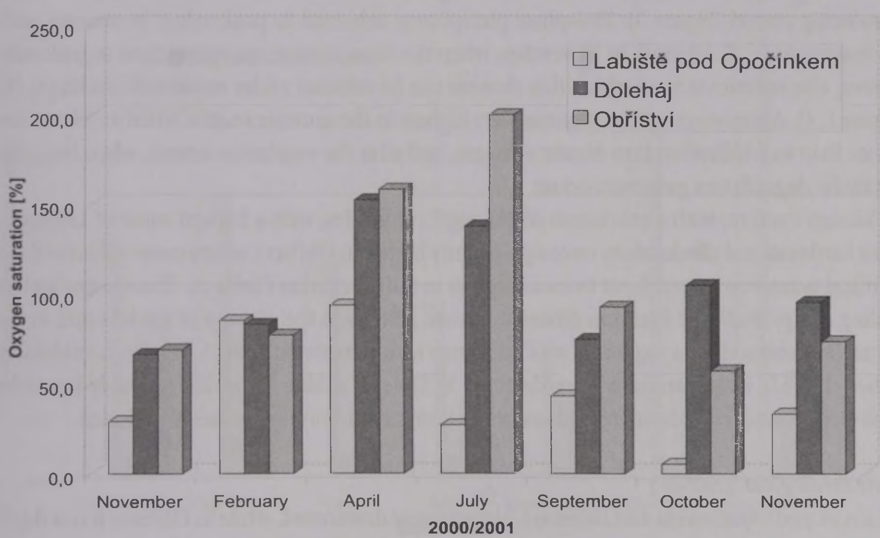

Figure 1: Mean values of oxygen saturation in investigated lakes

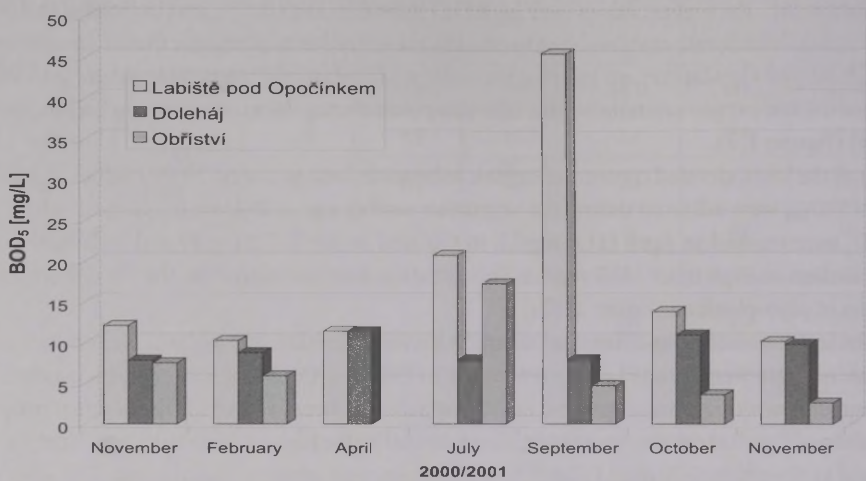

Figure 2: Mean values of BOD_5 in investigated lakes

in values of phosphate phosphorus during the vegetation season was also distinctly recorded in Obříství in April (0.01 mg/L). An interesting situation occurred in Labiště pod Opočínkem, where the inorganic nitrogen content remained practically on a constant level during the entire monitoring period (Figure 3). Phosphate phosphorus achieved its peak values in autumn, with the maximum of 0. 70 mg/L in November, when the sources were, excepting dead organic substances, also sediments from which this element can be released under reduction conditions [8] (Figure 1, 4). Ammonium concentrations were highest in the summer season, when its release was higher than its oxidization into nitrate nitrogen, and after the vegetation season, when intensive metabolic degradation processes occur.

Calcium content, with a maximum of 285 mg/L, chlorides, with a highest value of 130 mg/L, water hardness, and conductivity were significantly higher in Obříství, where mean values of these chemical parameters were about twice as high as in the other lakes (Table 2). The sources for this loading can probably be found in different human activity in the vicinity of the lake and in the Černavka stream, since a sugar mill was being run within its water basin. Likewise, considerably higher chloride concentrations were detected in Doleháj (Table 3), which probably has to be attributed, considering the increased concentrations of ammonium, to faecal pollution.

Hydrobiological analyses

In Labiště pod Opočínkem and Doleháj *Chlorophyceae* dominated, while in Obříství it was *Bacillariophyceae* (Table 3) These phytoplankton groups clearly indicated the eutrophic or hypertrophic character of the lakes [3], which was similarly indicated by the total values of phosphorus, with a maximum in Labiště pod Opočínkem in October (0.63 mg/L), and chlorophyll *a*, with the highest

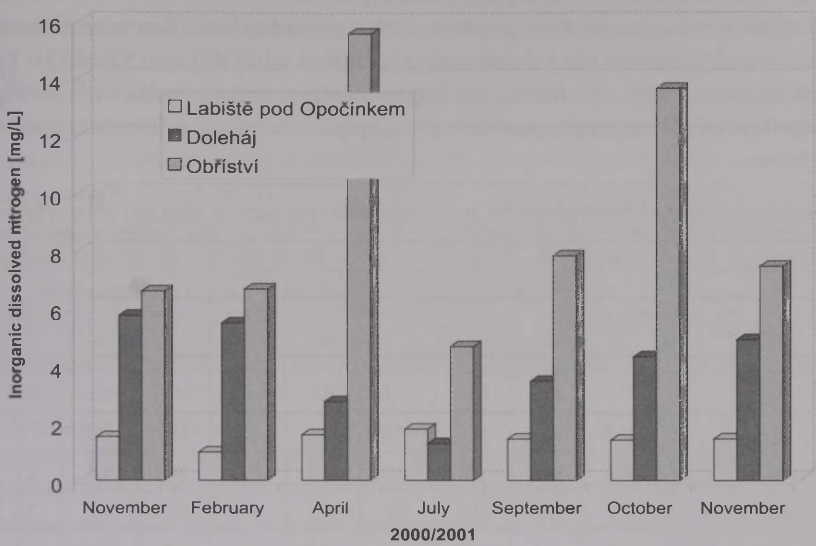

Figure 3: Mean concentrations of inorganic dissolved nitrogen in investigated lakes

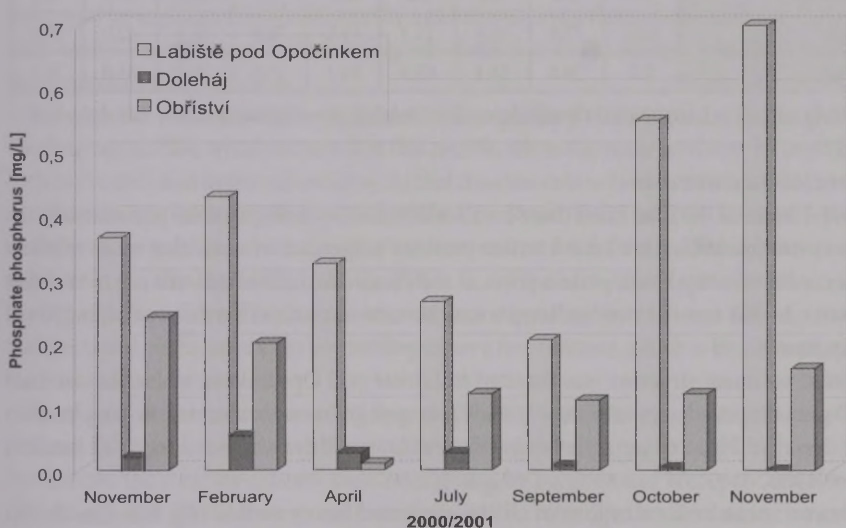

Figure 4: Mean concentrations of phosphate phosphorus in investigated lakes

value recorded in Obříství in June (279 µg/L) (Table 2).

The most numerous groups of zooplankton in the selected oxbow lakes were *Rotatoria* (in Doleháj) and *Copepoda* (in Labiště pod Opočínkem and Obříství) (Table 3). The registered absence of large specimens, e.g. *Daphnia magna*, corresponded with the high predation stress of planktonophagous fish [7]. *Copepoda* were only determined in the juvenile form.

Table 3: Representation of phytoplankton and zooplankton groups in selected oxbow lakes.

Sampling sites	1	2	3	1	2	3	1	2	3
	April 2001			June 2001			October 2001		
Groups of phyto- and zooplankton	[%]			[%]			[%]		
Bacillariophyceae	23.5	29.5	84.3	7.2	9.6	84.4	0.0	1.6	68.7
Chlorophyceae	26.8	56.6	6.7	66.0	28.2	8.1	21.7	14.3	7.5
Chrysophyceae	36.6	n.d.	0.6	5.2	n.d.	0.0	34.8	n.d.	5.2
Cryptophyceae	9.2	1.6	0.0	9.8	3.2	3.6	34.8	3.2	3.0
Cyanophyceae	0.7	5.4	n.d.	1.0	50.0	n.d.	0.0	52.4	n.d.
Euglenophyceae	0.7	4.7	6.2	7.8	8.5	2.7	4.4	27.0	7.5
Flagellata apochromatica	2.6	2.3	2.2	3.1	0.5	1.2	4.4	1.6	8.2
Cladocera	0.0	0.4	2.3	9.6	2.4	3.1	55.5	13.0	9.6
Copepoda	92.8	72.8	44.3	21.1	13.5	58.4	28.5	42.0	57.4
Rotatoria	7.2	26.8	53.4	69.3	84.1	38.5	16.0	41.0	33.1

Sampling sites: 1 = Labiště pod Opočínkem; 2 = Doleháj; 3 = Obříství; n.d. = not detected

Heavy metals in sediments

In the water basin of the Elbe River there are a lot of sources producing these pollutants. In the aqueous environment they are bound to fine particles suspended in water that settle in places with low current velocity. Under certain physical and chemical conditions metals can re-mobilize to the water. In this way the river sediments may become a source of further contamination of the environment.

The finest sediment structure was detected in Labiště pod Opočínkem, where the size fraction <63 µm comprised approximately 50 %; the largest grains were detected in samples from Doleháj (less than 20 % <63 µm). The largest share of fine particles was measured in all localities in deeper layers.

The lowest mean concentrations of all the measured heavy metals (Ag, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) were detected in samples taken in Doleháj (Table 4). This situation may have resulted from its early separation from the main stream of the Elbe River (50 years earlier than the dead arms of Labiště pod Opočínkem and Obříství) and its relatively long distance from the river channel, which means that the fine particles binding heavy metals may have settled before the water reached the lake through the inlet channel. The fact that industry in the Kolín industrial area is not as important as in the two remaining zones may also have contributed to lower pollution levels [20]. The highest mean concentrations of Ag (15.6 mg/kg), Co (21 mg/kg), Cr (255 mg/kg) and Zn (1022 mg/kg) were measured in Labiště pod Opočínkem (Table 4). The source of this high content of heavy metals may be industrial plants in the Hradec – Pardubice agglomeration, e.g. Synthesia Semtín a.s., Foma Hradec Králové, or waste water from the Opatovice Power Plant sludge lagoon. Concerning Cd (6.4 mg/kg), Cu (133 mg/kg), Fe (28 742 mg/kg), Hg (5.80 mg/kg), Mn (1 950 mg/kg) and Pb (375.8 mg/kg), the highest mean concentrations were registered in Obříství (both samplings) (Table 4). The probable source of this high concentration is the Spolana Neratovice plant, and also Kaučuk Kralupy nad Vltavou; some impact could also come from the Mělník Power Plant.

The depth gradient of the heavy metals differed from place to place (Table 4). Similarities were only detected for Cd and Pb. The upper layer of the sediment in Doleháj was rich only in Ag, Cd and Mn; the other metals had higher concentrations in deeper, and consequently older, layers. In Labiště pod Opočínkem a high content of most heavy metals was, on the other hand, found in the upper layers: Ag, Cd, Cr, Cu and Zn. This was similar in samples taken in Obříství. Here the upper layer was first of all rich in Cd, Co and Fe (sampling 2001) (Table 4). Assuming that sediment age increases together with increasing depth, we conclude that the localities were probably contaminated at different times. This fact could be explained by the diversified development of the industrial plants causing this load. Unfortunately, no detailed dating was done that could contribute to identification of the sources of this pollution.

In September 2002 sediment samples were taken again in the Obříství locality after the 'century flooding' of the Elbe, which occurred in this month, when the water level rose by several metres both in the river and in the oxbow lakes. At that time the oxbow lakes were connected to the river and the concrete culvert spilled water into the Elbe River. These samples contained, compared with the above-mentioned ones, higher concentrations of Cd, Fe and Pb, but lower concentrations of Co, Cr, Cu, Hg, Mn, Ni and Zn (Table 4). All the heavy metals monitored – except Cd, Co, Hg and Pb – showed higher concentrations in upper sediment layers. The explanation for this fact could be the extremely low settling of very fine fraction, which is bound willingly by all the monitored elements.

For the assessment of sediment loadings with heavy metals the geo-accumulative index Igeo [26] was calculated, considering the concentration of elements in the natural geogenic milieu. For this case the contents of heavy metals designated by Turekian and Wedepohl, 1961, in natural clayish sediment (Table 4) were used as reference. The value Igeo is calculated according to the formula:

$$I_{geo} = \log_2 (Cn / (1.5 \times Bn)$$

Table 4: Heavy metals in sediments of the investigated lakes

	Natural geogenic milieu	0.07	0.3	19	90	45	47 200	0.40	850	68.0	20.0	95
	Heavy metal	Ag	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	[mg/kg]											
Labiště p.O.	mean value	15.6	4.0	21	255	87	25 520	1.78	569	44.7	114.3	1 022
	upper layer	28.4	5.0	21	316	117	25 020	2.30	485	45.0	110.0	1 483
	middle layer	14.3	4.2	23	252	85	27 353	2.39	679	47.0	115.0	1 049
	deep layer	4.0	2.7	18.	198	59	24 187	0.64	543	42.0	118.0	533
Doleháj	mean value	13.0	2.3	18	94	34	16 200	0.41	247	32.5	71.8	168
	upper layer	13.5	3.5	17	75	28	13 200	0.39	310	30.5	66.5	156
	deep layer	12.5	1.0	19	114	41	19 200	0.43	184	34.5	77.0	180
Obříství I	mean value		4.3	19	241	133	22 833	5.80	1 950	44.7	184.0	943
	upper layer	n.d.	4.7	22	231	134	27 200	3.60	1 250	50.0	145.0	650
	middle layer	n.d.	4.0	19	266	125	22 400	7.20	1 720	50.0	173.0	1 030
	deep layer	n.d.	4.3	17	225	139	18 900	6.60	2 880	34.0	234.0	1 150
Obříství II	mean value	8.4	6.4	15	210	115	28 742	3.58	1 030	35.5	375.8	777
	upper layer	13.3	7.5	13	300	144	30 075	4.53	1 128	42.3	314.1	965
	middle layer	6.6	7.5	17	205	121	29 858	5.17	1 080	34.0	492.5	958
	deep layer	5.3	4.3	16	125	80	26 292	1.05	884	30.1	320.8	409

Natural geogenic milieu by Turekian and Wedepohl, 1961; Labiště pod Opočínkem, Doleháj, Obříství I – sampling in 2001; Obříství II – sampling in 2001; n.d. = not detected

Where Cn is the measured concentration of the metal being considered, Bn is its background concentration in natural clayish sediment and the coefficient 1.5 involves the natural variability of the milieu. From the calculated Igeo values was determined the contamination of sediment.

The sediments in Labiště pod Opočínkem, Doleháj and Obříství displayed very high contamination with Ag (Table 5); high contamination with Cd was also proven in the case of Labiště, as well as Obříství. Here high pollution with Hg was detected as well (sampling 2001) and Pb (sampling 2002). So, the situation after the flood in the Obříství locality worsened only concerning Pb, but the loading of sediments with Hg dropped (Table 5). These results demonstrate the fact that, if no reworking or leaching occurs, the 2002 flood of the Elbe River has probably not significantly loaded the studied lakes with heavy metals. However, it might be possible that Elbe floods that occurred in the past were higher loaded with heavy metals than the 2002 flood, and thus significantly contaminated the studied lakes.

Table 5: Classes of sediment contamination of the investigated lakes by Müller, 1979

I_{geo} - Classes	Ag	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Labiště 2001	6	4	0	1	1	0	2	0	0	2	3
Doleháj 2001	6	3	0	0	0	0	0	0	0	2	1
Obříství 2001	n.d.	4	0	1	1	0	4	1	0	3	3
Obříství 2002	6	4	0	1	1	0	3	0	0	4	3

0 = unpolluted; 1 = unpolluted to moderately polluted; 2 = moderately polluted; 3 = moderately polluted to strongly polluted; 4 = strongly polluted; 5 = strongly polluted to very strongly polluted; 6 = very strongly polluted; n.d. = not detected

Discussion

The three oxbow lakes of the Elbe River mentioned provide, as do dozens of others, indisputable evidence of the original course of the Elbe river channel [2]. Very often they retained their natural character and so they are important ecological landscape elements. The locality Labiště pod Opočínkem was, for that reason, proclaimed a nature reserve in 1982 [6].

In spite of the identical origin of these lakes, major differences were found. From physical parameters these were, for example, conductivity, the values of which were nearly doubled in Obříství [32]. The oxygen deficit in the pool at Labiště pod Opočínkem and the very high concentration of phosphates related to the deficit were very surprising. In this lake levels of nitrate that were several times lower were also detected, which could be related with the probable insufficient oxidization rate of ammonium [19]. On the other hand, water in all the monitored arms contained a relatively significant load of organic substances, which may be partially due to their eutrophic status. The results of hydrobiological analyses are in correspondence with the research of Hrbáček et al., 1965, Hrbáček, 1966 and Kylbergerová, 1997.

Significant differences were detected when measuring heavy metal concentrations in sediments, depending on the age of the individual lake, its connectivity with the river and industrial development in the region of selected localities. The content of heavy metals in sediments of the Elbe River was studied e.g. by Studihrad, 1992, Borovec et al., 1993, Svátek , 1994, or Veselý and Gűrtlerová, 1996.

The vertical gradient of heavy metals in the sediments was also very interesting. Unfortunately, because of the missing dating, the contamination sources could not be clearly identified. The analysis of results assessing the impact of flooding on the Elbe River in the Obříství locality in September 2002 did not prove that the new material brought by the flood caused a higher concentration of heavy metals and contaminated the natural milieu.

Conclusion

The old flood-plain meanders of the Elbe should attract significant attention in future because, apart from being home to a variety of rare species, they represent a sort of river archive where we can get from valuable data on the original river beds, on water quality development in the ecosystem, on possible pollution sources, and also on the level of risks represented by contaminated sediments. It is also necessary to consider the importance of these old meanders for flood protection, as, for example, controlled retention polders.

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Surface water quality in small catchment areas after the construction of wastewater treatment plants

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Abstract
Small catchment areas are usually not equipped with wastewater treatment plants. This situation is changing nowadays. Changes in water quality caused by the construction of water treatment plants have not been satisfactory described. This project compares water quality in three types of watersheds – those with water treatment plants, those without them and uninhabited watersheds. For evaluation purposes, we chose the most commonly used water quality indicators: conductivity, dissolved oxygen, BOD_5, COD_{Cr}, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$ and P_T. The project is still underway, but the interim findings show that changes are sometimes barely noticeable or can even worsen water quality.

Keywords: Self-purification, small catchment areas, wastewater, water quality, water treatment plants

Introduction
Attention to surface water quality has recently shifted from larger to smaller catchment areas, because small brooks often have worse water quality than large rivers. One of the reasons for this situation is the presence of waste water treatment plants in larger cities, and their absence in small villages. In smaller cities, new or renovated older treatment plants have often been built in recent times, and this also improves the quality of surface water.

The main sources of water eutrophication in small catchment areas are sewage and agricultural pollution. New treatment plants constructed in small villages are mainly built with a standard format that is not adapted to local conditions. Water is polluted on discharge from the treatment plant into small brooks, which have a much lower volume of water. Therefore the process of self-purification cannot take place quickly enough.

Some researchers maintain that not all water treatment plants (WTP) in small villages improve water quality. This situation has been little observed and monitored until now. Therefore the most important task of this project should be the characterization of water quality changes after the construction of small WTPs. The other goal is to compare water quality in different types of watersheds – with and without WTPs, and catchment areas without sewage water pollution.

Selected indicators used for water quality determination, data sources

For this project, 9 indicators were chosen to determine water quality: conductivity, dissolved oxygen, BOD_5 (biological oxygen demand in 5 days), COD_{Cr} (chemical oxygen demand, performed using dichromate method), $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$ and P_T. Indicators such as temperature, pH, base and acid capacity, water hardness, Ca^{2+}, Cl^- and Fe^{3+} were initially also considered for the description of water quality, but in the end they had to be omitted because of the enormous amount of data. There is a need for a regular, frequently measured (monthly) data series. Such data can only be found in state monitoring systems, because no university in the Czech Republic has as long data series as state institutions. Nearly 50 profiles were chosen from 3 state monitoring networks (1361 profiles) that are suitable for the purpose of this project. Chemical indicator values were then provided by the Agricultural Water Management Authority (Zemědělská vodohospodářská správa).

Watersheds specification

The most important condition for this project was the study of comparable profiles that had been regularly and adequately measured over a long period of time. In the end, of the 1361 measured profiles that could be suitable for this project (these profiles were defined as small watersheds), 49 profiles were chosen and divided into the 3 following groups: profiles in watersheds with operating WTPs; profiles in watersheds without WTPs, where sewage water runs directly or indirectly into the brook; profiles in watersheds without sewage water (without settlement). The fundamental characteristics of the selected watersheds are shown in the following tables (WTP – water treatment plant):

Table 1: Number of watersheds according to watershed surface area

Watershed surface area	with WTP	without WTP	inhabited
up to 5 km^2	4	5	0
5–10 km^2	10	6	5
10–15 km^2	7	1	4
15–20 km^2	4	1	2

Table 2: Number of watersheds according to main Czech watersheds

Watersheds	with WTP	without WTP	uninhabited
Vltava	13	2	7
Labe	3	8	3
Ohře	5	0	0
Odra	1	0	0
Morava	3	3	1
Total	25	13	11

Table 3: Number of watersheds according to number of citizens in watershed

Number of citizens	with WTP	without WTP	uninhabited
up to 300	1	4	0
300–500	5	4	0
500–1000	2	4	0
1000–1500	9	0	0
1500–2000	8	1	0

Table 4: Number of watersheds according to flow rate and presence of pond

	with WTP	without WTP	uninhabited
Number of watersheds with pond	10	4	3
Flow rate (Qa) $l.s^{-1}$	4 – 130	4 – 100	25 – 100

The selection of profiles in the group studied was made especially according to the two following criteria:

1. The maximum number of inhabitants was limited to 2000 (the criterion for state financial support for small WTP)

2. The smallest possible surface area of the watershed was preferred (because of the better transparency and thus easier assessment of land use and the smaller possibility of errors)

Before the addition of other criteria, it was necessary to correct some of the data, because they were not current. The updating of the data files had to be done by emails and phone calls to village mayors and sewer administrators, because of the absence of an overall data source. Further catchment requirements decreased the number of suitable study areas:

- minimal length of brook (in order to minimize the impact of other pollution sources and better assessment of the self-purification process)
- minimal neighbouring agricultural areas (in order to decrease the possibility of fertilizers' nutrients income)
- study area with only one settlement or with one settlement and sparsely populated surround-

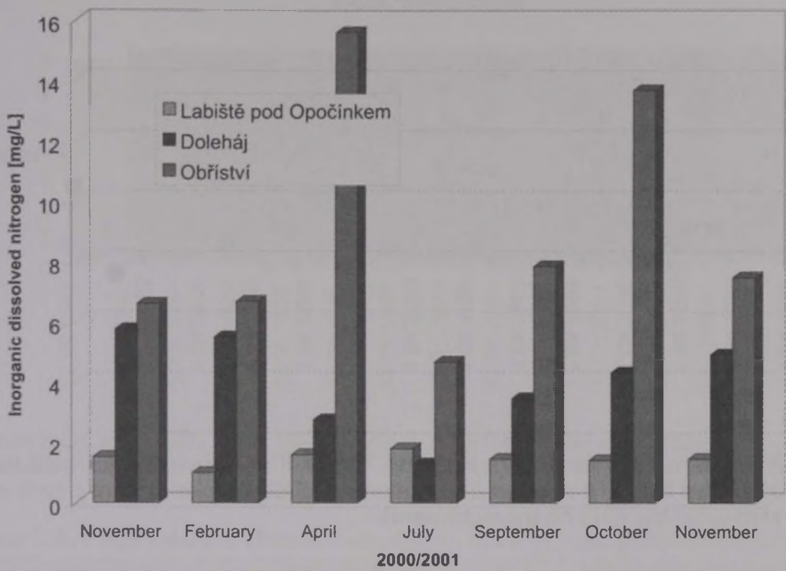

Figure 1: O_2 and BOD_5 from 1994 to 2005 in Dolní Lukavice. The WTP was put into operation in 1999 (August – December). Slight changes in O_2 and BOD_5 are evident from 2003.

ings (a minimum of secluded dwellings because of bad self-purification assessment)

- Approximately equal areas covered by forest
- Approximately equal brook flow rate (to ensure better comparison)
- presence of WTPs - for the group with WTPs (some settlements pipe their sewage water to a WTP in another village)
- similar sewage pipeline conditions and percentage of connected households

Processing and structuring of hydrochemical data

The final selection of the suitable study areas was done after the hydrochemical data was obtained. The chemical analyses used in this project were taken from spring 1993 to summer 2005. Water characteristics with graphs were made for every single study catchment area. Group analyses were then made for each of the three groups so that they could be compared. The flood of August 2002 also had to be taken into consideration, since it washed away some of the WTPs and thus changed the water quality indicator values.

Water quality change after WTPs were put into operation

In order to assess the effect of WTPs on surface water quality, long series of measuring are neces-

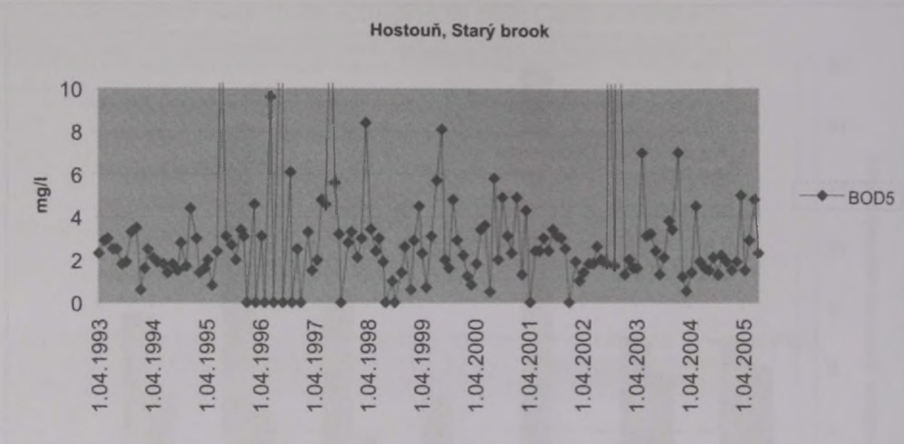

Figure 2: BOD_5 from 1993 to 2005 in Hostoun. The WTP in Houstoun was built from 1995 to 1996. After the WTP was put into operation, BOD_5 oscillations are clearly evident (the zero value signifies no measurement).

sary. The WTPs in the chosen watersheds were installed at different times, but the most suitable time for putting WTPs into operation in this project was between 1997-8 – 2001-2. In the group of watersheds with WTPs there are 25 study areas, but only 8 of them have a new WTP built between 1997 and 2002. Putting a WTP into operation caused both an improvement and a deterioration in water quality. In some study areas the water quality remained unchanged.

The oscillations of some indicators increased after WTPs were put into operation in some study areas.

Main characteristics of catchment areas without WTPs and uninhabited catchment areas

In the study areas without WTPs, there is a greater stability in the monitored indicators. The natural annual fluctuational change of some indicators are registered in these watersheds because of the absence of WTPs. Differences usually only involve isolated values. All of the changes in catchment areas without WTPs are slight and span a relatively long period of time.

Conclusion

The improvement in surface water quality through WTPs in small watersheds is clearly not as intensive as was generally intended. This project is not yet complete, and therefore evaluations are not complete, and as a result only partial results can be presented. An overview of average values for different catchment areas is provided in the table below.

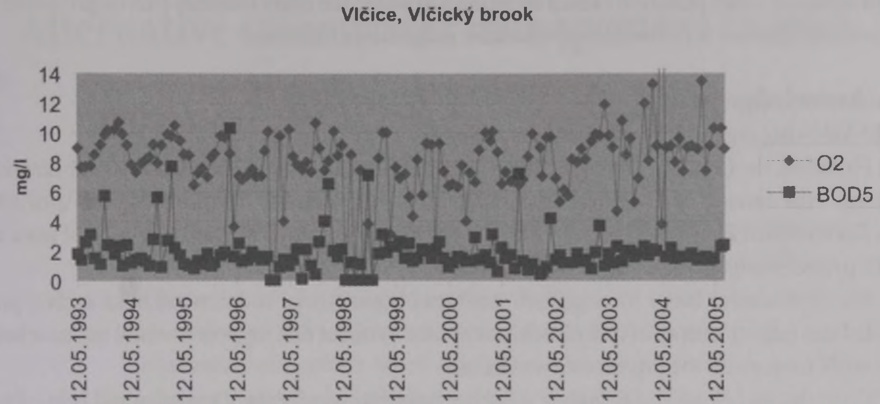

Figure3: O_2 and BOD_5 from 1993 to 2005 in Vlcice. In this graph the natural annual fluctuation can be seen.

Table 5: Average values of chosen indicators in three groups of catchment areas

Indicators	unit	Catchment areas		
		with WTP	without WTP	uninhabited
O_2	mg/l	9.243	8.999	9.639
BOD_5	mg/l	7.713	3.636	4.613
COD_{Cr}	mg/l	28.406	19.636	26.973
TOC	mg/l	10.883	8.183	9.797
k	mS/m	54.855	58.752	36.273
$N\text{-}NH_4^+$	mg/l	1.955	0.806	0.753
$N\text{-}NO_2^-$	mg/l	0.129	0.081	0.055
$N\text{-}NO_3^-$	mg/l	5.356	4.781	4.535
P_t	mg/l	0.799	0.398	0.288
$P\text{-}PO_4^{3-}$	mg/l	0.629	0.309	0.196

This table shows the average values of selected indicators for the 3 groups of watersheds (e. g. with WTP) that contained all of the study area's values within a given group. In the two columns for inhabited areas, the better water quality values are highlighted in grey. It is surprising that the better values of the indicators BOD_5, COD_{Cr} and TOC in inhabited watersheds without WTPs are clearly better than in watersheds with WTPs. Moreover, almost all of the indicators show better values in areas without WTPs. Further research is required to determine the reason for this situation. One of the biggest parts of the further research is the more accurate evaluation of land use in the watersheds. Although the measured profiles were located especially for the estimation of water pollution caused by municipal water, the other incomes (from agriculture or from atmosphere) of nutrients may also have a significant influence.

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Alternative stormwater management in Pécs

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Abstract

Urbanization interrupts and has an extremely adverse impact on the hydrological cycle. The spreading sealed surfaces accelerate runoff and cause different types of hydrological problems. The unsustainability of the urban water system is not acknowledged here in Europe, because water works are usually able to supply the inhabitants with potable water. Another problem is the neglect of the impact of urbanization on the hydrological cycle, the complexity of our urban water budget is a great challenge to the contemporary researchers. The calculation of rainfall, interception and infiltration values is a very complicated procedure, since the modelling of the interaction between urbanisation and the water cycle yields unreliable results. Our study reveals one type of research method in urban hydrology, which is a possible way to introduce a new type of stormwater management practice. We investigate three different built-up areas in the urban watershed of Pécs city. These experimental subcatchments are representative of other estates of the city. For this reason we have developed a map of the most suitable Low Impact Development (LID) solution for stormwater management in the residential areas of Pécs.

Keywords: Sustainable water management, stormwater management, low impact development, hydrological modelling, infiltration, runoff rainwater harvesting, flash floods

Introduction

At the beginning of the 21st century it became quite accepted that the extension of the urban stormwater sewer system is not the final solution to avoiding flash floods and other disadvantageous impacts of urbanization on the hydrological cycle [7]. The expanding quantity of impervious surfaces increases flood risk over urbanized areas, and the technocratic answer is highly limited by natural and social conditions. In this way we have to replace the conventional pipe technology of surface water management with a sustainable one. Recently this new practice is called LID (Low Impact Development). LID means «the integration of site ecology and environmental goals and requirements into all phases of urban planning and design from the individual residential, commercial and industrial site to the entire watershed»[7]. This study proposes environmentally sensitive runoff management for the city of Pécs, with special regard to utilization concept. Thus the main objectives of our work are to solve site-specific hydrological, economic and social problems related to water management in peculiar environmental conditions, and point out the adequate factors to which we must pay attention during alternative stormwater management planning.

Materials and methods

Our primary goal in this comprehensive study was the use of various spatial geoanalytical and hydrological models. Firstly the 10-metre contour lines were digitized from 1:10,000 topographic maps using ArcGIS (version 8.3). A digital elevation model (DEM) of the study areas and the immediate vicinity was created, and from the DEM we analyzed the surface runoff, running IDRISI (version 3.2) GIS Analysis menu's Runoff option. We overlay the surface runoff map above the city street map, and allocate the concentration point of the planned study areas. Due to this digitized point we could run the Watershed option of IDRISI (version 3.2), which separate the studied watersheds. Thus we analyzed the study areas, digitized the impervious surfaces and calculated the percentage of it over the experimental fields (using ARCGIS version 8.3) (Table 1).

Tabel 1: Conditions of study areas

	Name of the subwatershed	Size of the subwatershed	Slop %	Storm sewer system	Hydrogeological status
1	South Makár	8,5 ha	20–50	unsolved	over the deep groundwater
2	Hunyadi street	106 ha	10–40	partly solved	over the karstic aquifer
3	Melinda street	12 ha	0–5	solved	over the deep groundwater
	Name of the subwatershed	**Built-up type**	**Future trends**	**Impervious surface %**	
1	South Makár	new building area	increasing impervious areas	5,7	
2	Hunyadi street	traditional build up area and forest	aged system, increasing erosion	13–53	
3	Melinda street	block of flats	aged system	24–87	

We transformed property maps and orthophotos to obtain the most detailed and recent information on land cover. Another very important methodological part of our study was the field trips, during which we modified our computer-made watershed maps using field observations. During our field work we tried to fit in the anthropogenic effects on the natural conditions. The roads, footpaths and the sewer system alter runoff processes and increase or decrease watershed size. By using the stormwater management model SWMM 5.0 and diurnal rainfall data (August 22, 1998 and September 5, 2001), we estimated the effectiveness of the recent ditch and gutter systems. The program also allowed us to model various scenarios. By changing the input data, such as the increasing number of residential properties and impervious surfaces, we modelled the altered hydrologic patterns and the volume of surface runoff, as well as the potential infiltration at various locations in Pécs. Based on computer modelling, we were able to determine the place, the method and the general criteria for the intervention in the present runoff situation to improve urban water management. In order to evaluate the alternative possibilities for stormwater management, we overlaid different layers (geological, slope, build-up type, city structure), and thus we were able to analyze the most suitable type of alternative stormwater management for the examined areas.

The Mecsek Range has always strongly affected the development of the Pécs. Despite the lack of surface water, the limestone aquifer of the Misina – Tubes range provided a favorable habitat for the first settlers in the area [6]. The varied rock types and the geological and tectonic setting of the Mecsek Hills created a diverse topography in the region, compared to the surrounding area. Although the development of the Misina – Tubes Range was primarily affected by the dissolution of limestones and other karstic processes, tectonic movement left its distinct footprints on the surface. Due to the asymmetrical uplift of the Mecsek Mountains, the layers are tilted, and a deep north-south valley system developed in the southern foreground of the Mountains. A broad foothill region was formed in the southern foreground of the Mecsek Mountains between the Pécs Halfbasin (elevation: 160 m a.s.l.) and the Misina-Tubes Range (380 m a.s.l.). Several springs are found along the outcrops and scarps created by vertical movements along fault lines on the boundary of the limestone and sandstone areas. The parallel valleys are bordered with narrow ridges and are fluvially formed with seasonal streams.

The valley heads are located on the border of the foothills and the Misina–Tubes range. The former deposition of sea sediments created a terrace-like surface here. Since the former abrasion terraces are connected by several steep slopes, the tributaries of the Pécsi-víz (main stream of the region, flowing east to west) therefore bear a considerable gravitational and erosion potential. The high potential energy of these streams is proved by the several alluvial fans that have accumulated along the northern border of the Pécs Halfbasin. By today, most of the alluvial fans have become covered, and consequently a substantial amount of sediments needs to be removed from paved and impervious surfaces and ditches following intense rainfall events.

The southern slopes are favoured for various fruit crop production, and here one can find orchards and vineries that were subsequently overtaken by residential areas, spreading continuously uphill toward the summit region of the Mecsek Mountains. However, urban development neglected the topographical effects and generated diverse eco-social environmental problems. The city's road system was established in the mid-1950s, and thus it is unsuitable for the increased traffic of today. Similarly, the strong relief hampers the development of the sewage and drainage systems. The narrow and densely populated valleys are unsuitable for the establishment of stormwater reservoirs. The long, north-south ridges between the valleys create a natural barrier for the development of a reservoir system running along the southern edge of the Mecsek Hills. The lack of this perennial reservoir system results in the seasonal but intense flooding of the low-lying (valley bottom) districts of Pécs. In recent years the development of the sewage system has begun on the southern foothills of the Mecsek. With the appearance of such utilities, construction permits are more easily issued to those who plan to build on real estate at higher elevations (hitherto non-residential areas, mainly orchards and vineyards) in the Mecsek Mountains. As a result of the infrastructure development, the surface area of pervious (non-sealed) surfaces will likely decrease in the near future. The urbanization process on the higher and steeper slopes of the Mecsek Mountains creates further problems for stormwater conduit, and economic losses due to flash floods are expected to be more substantial. Unfortunately very few residents are trying to construct pools or reservoirs or increase infiltration by establishing lawns, for example. bove-mentioned processes create additional costs for local governments and residents. The maintenance costs of the existing precipitation canals are continuously increasing, and decongestion and ditch broadening and cleaning is a continuous expense for the local government.

Results and discussion

Infiltration and aquifers

Increasing infiltration helps us to reduce the flood risk and partly control contamination processes in urban areas. In order to determine the potential of this method, we first determined those parts of the city in which deep aquifers are located. Then we drew a parallel with the slope category layer, and also overlay with the distribution of built-up areas in the city. The three superimposed layers highlighted the parts of the city where alternative stormwater management could accelerate the recharging of deep aquifers. We assigned different types of alternative infiltration techniques to the built-up districts (Table 2) [1]. We modelled a precipitation event on the sample water catchments for the day of September 5th, 2001, as here several rain gauges reported 100+ mm of precipitation, with a maximum rainfall of 118.9 mm. The following conclusions were drawn after the investigation. First, over the Misina-Tubes karstic aquifer the most suitable techniques are vegetated strips and level spreaders, especially to reduce the runoff from the footpath. Another adequate solution in garden houses are dry wells. We also performed some calculations to provide data about the karstic aquifer discharge losses over the Hunyadi Street urban watershed. If we increase impervious surfaces by 20 % over the two sub-watersheds located on the Misina-Tubes karstic aquifer, about 3 mm in infiltration losses was a considerable amount of the total of 85 mm precipitation (over 12 hours) with changing intensity. This means an approximately 743 m^3 loss for the karstic aquifer during the above-mentioned curve number. Second, those districts that are situated around the industrial areas or the main roads are not conducive to quality control, and thus we have to integrate some other technique like a vegetative filter strip and a buffer zone as well. Third, in the case of the traditional built-up type of city, the improvement of infiltration is an unsuitable solution, because the basements of the buildings are too dense, and thus water damage will appear in this type of zone. Fourth, in those blocks of flats where the traffic is quite low and that are situated at border of the city, all infiltration techniques are suitable. After the hydrological modelling of the 12 sub-watersheds of Melinda Street, we are able to estimate an average infiltration rate over this type of watershed. If we load up the model with the rainfall data from September 5, 2001 (12 hours, 85.2 mm) the total infiltration is 9.21 mm, which could be multiplied by alternative stormwater management. Of course the hydrological situation of our storm events is not favourable for infiltration, but if we simulate low intensity rainfall, then approximately 33 % of the precipitation can infiltrate, but if we apply alternative stormwater management, this ratio could be doubled. The best location for the LID constructions is always the upstream part of the sewer system.

Table 2: Alternative LID techniques to improve the infiltration over the study fields (the darker colors mean a more suitable technique for the site).

Techniques		Huhyadi Street	South Makár	Melinda street
Level spreaders/ vegetated strips	design for converting concetrated flow to diffuse flow			
Infiltration basins	water impoundment for retetion of surface runoff			
Infiltration tranches	trenche backfill by aggargate for temporaly storage the surfac runoff			
Porous pavements	constructing by porous paving material, which allows the temporary storage for captured precipitation			
Dry wells	excavated pits fill up with aggregate			
Bio-retention area/ rain garden	designed for reduce the surface runoff from contaminated area (parking places, roads), and retention of the water by using plants			

The South Makár sample area also saw a remarkable change in the trend of infiltration, if we increased the impervious surface over the watershed (Fig. 2). The increased surface runoff simultaneously decreases the recharge rate of the aquifer, thus considerably affecting long-term water supply.

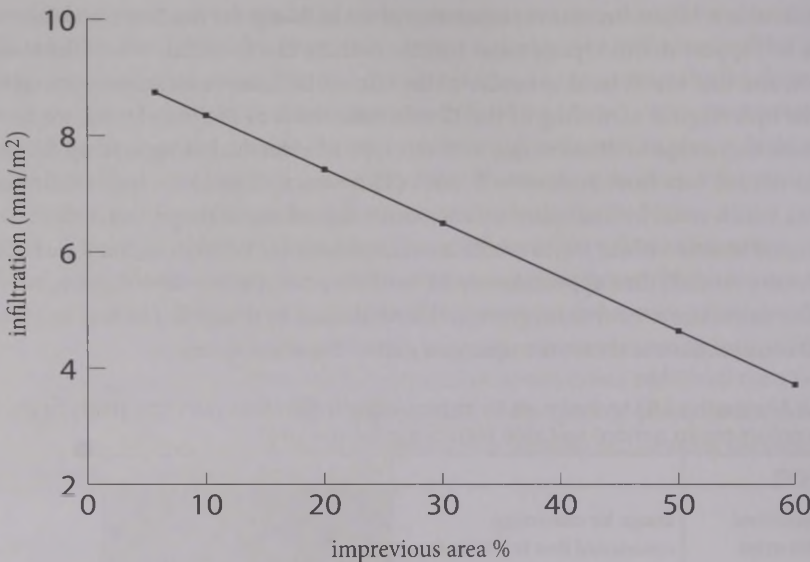

Figure 2: The trend of infiltration over the South Makár study area

Beneficial use

The beneficial use of the stormwater partly overlaps with the re-use of the collected, stored rainwater, and with use for non-potable goals. The capacity of this technique depends to a great extent on the impervious surface over the watershed of the tank. According to the literature, there are four major types of precipitation re-use. 1) In technological processes, industrial re-use of rainwater can be accomplished, but production costs can also be reduced by rainwater re-use. 2) On a public level, re-used rainwater can be used for irrigation and for microclimate and air quality improvement. In the latter two cases, by applying physical straining and pre-sedimentation cells, appropriate water quality can be achieved. 3) In households, with the exception of drinking water, re-used rainwater can be broadly utilized for everyday purposes: according to three water quality measurements, without chloride addition the rainwater is appropriate for bathing household standards. With chloride addition, outstanding water quality can be achieved (1 sample), and our result is also supported by other studies [3, 4]. 4) Another alternative solution is the development of «green-roofs». Green roofs are covered with a thick layer of vegetation, where plants retain water, increase the insulation properties of houses, and improve water quality by increasing humidity. This type of water re-use would be desirable in closely built-up downtown areas, as this district lacks appropriate space for the development of cistern systems, and appropriate water standards are difficult to achieve due to pigeon droppings (Fig. 3.).

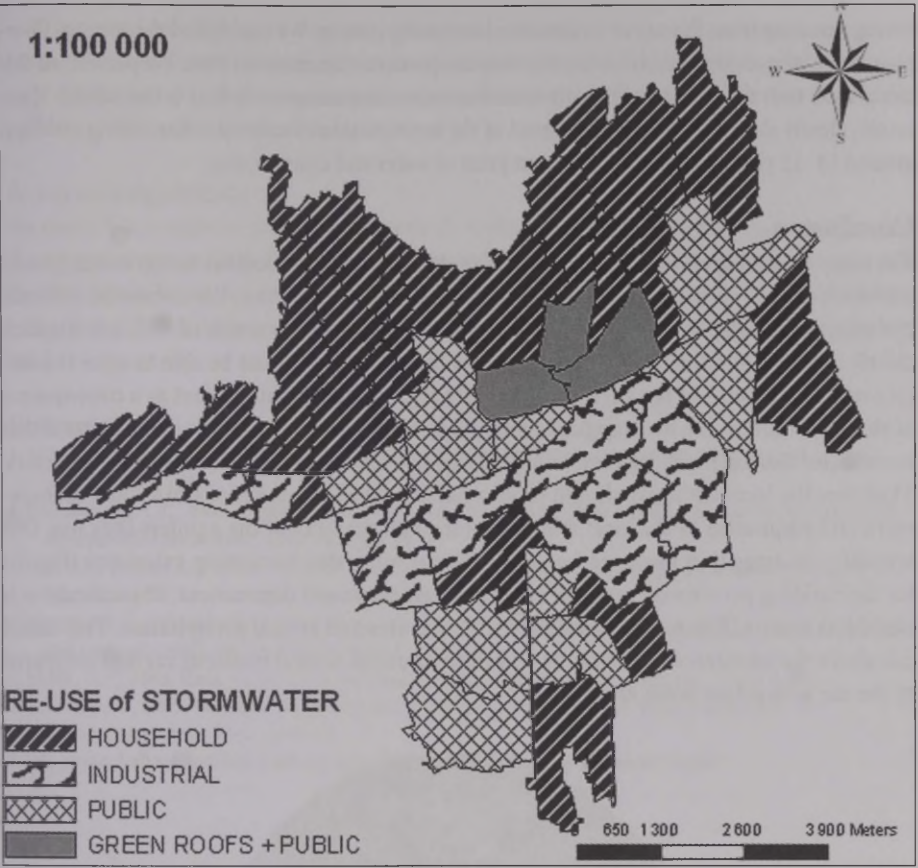

Figure 3: The most adequate techniques for the re-use of rainwater over the city of Pécs

During our investigation we assessed the present and expected future building density and functional structure of the city, and compared it to the physical geographical conditions. Using this method we denote the most adequate alternative technique for the re-use of rainwater (térkép, táblázat). Apart from the city centre, the rainwater harvesting technique could contribute to reducing the risk of flash floods and the extraction of the local deep aquifers. According to our calculations, if a rainwater collecting system is introduced over the area of residential houses, approximately 726 660 m^3 could be saved from the aquifers, amounting to 13% of yearly communal water consumption. We use another method to estimate the beneficial effects of the re-use of rainwater. Over the examined study fields, where construction activities will take place in the near future, we alter the present impervious surface to the expected one, and load this data into the hydrological modelling program.

Another interesting result of our research was the determination of the annual household water saving resulting from the use of a rainwater harvesting system. We multiplied the average floor-plan area of the residential houses by the 98-years precipitation mean of Pécs. We performed this calculation over those parts of the city where stormwater management is as yet unsolved. These results clearly show that the return period of the construction of rainwater harvesting system is around 13–15 years, based on the present price of water and construction.

Conclusion

The main objectives of our study were to solve site-specific hydrological, economic and social problems related to surface water management in the city of Pécs. We simulated different hydrological conditions through computer modelling, and the result of this investigation clearly revealed that the conventional pipeline technique would not be able to solve the surface runoff problems of the Pécs. It can rapidly replace surface runoff, but as a consequence of this intervention the hydrological cycle will be interrupted. Our study demonstrated that stormwater management is a very complex issue in Pécs due to the natural and social factors. Therefore the local authority should promote alternative techniques of stormwater management and emphasize to the local inhabitants the vulnerability of the aquifers they use. Our scientific investigation motivated us to develop a rainwater harvesting calculator (Fig. 4.) for the building permission procurers at the city development department. This calculator is based on cistern efficiency, i.e. household size, roof area and annual precipitation. This model calculates the investment return time and the amount of annual financial savings compared to the use of pipeline water alone.

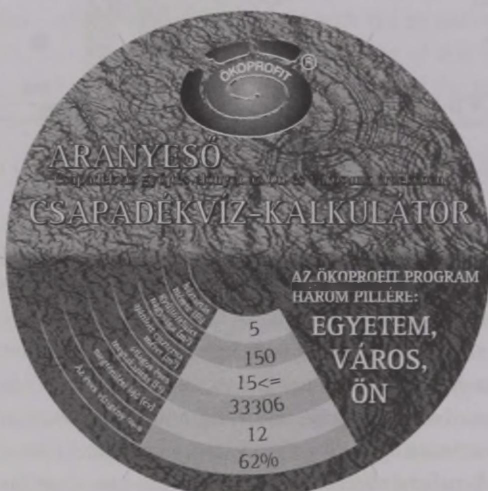

Figure 4: Rainwater harvesting calculator, tool for residents to estimate the cost of the re-use of rainwater.

As our main conclusion, we emphasize that the traditional custom of stormwater management is not suitable in diverse natural and social conditions, and careful design and the contribution of local residents and authority is also necessary to diminish the above-mentioned environmental problems and create a sustainable future.

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A few problems of Lake Kis-Balaton

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Abstract
Kis-Balaton is one of the most valuable wetlands in Hungary. Due to the realisation that it plays an important role in the preservation of the water quality of Lake Balaton, however, it was saved from the complete drainage that began in earlier centuries, but it has lost much of its original area.

In the 1960s and 1970s the construction of the water protection system of Kis-Balaton resulted in the appearance of sedimentation, the spread of algae and water-grass in the bay of Keszthely, in the interest of the protection of Lake Balaton. The constructed parts of the water protection system have two fundamental aims: the protection of water quality and of wetland habitats.

The results have shown that there are some differences in the objectives of water quality and nature conservation, and the needs of one sometimes exclude the needs of the other. In order to solve these problems, the plans need to change. Water cleaning mechanisms that use natural macrophytes should be favoured, and thus the transformation of the two reservoirs into real swamps should be attempted.

Keywords: Lake Kis-Balaton, Lake Balaton, Lake Hidvégi, Lake Fenéki, Ingói Grove, Zala River, wetland, macrophyte vegetation, regulation, drain, spillover, plant nutrients, eutrophication, algae blooming

Introduction
Lake Balaton is the biggest lake in Central Europe; it is admired and visited by many people and is also well known in the context of international tourism. Places that are farther from Lake Balaton are less often visited by tourists. One example is Kis-Balaton, which is a swampy, boggy wetland near the southwest shore of Lake Balaton.

Lake Kis-Balaton was originally a bay-like part of Lake Balaton with rich wetland vegetation, so the incoming river water was filtered and controlled by the plants in the swamp before the 18th century (Fig. 1). It is a protected nature conservation area of Balaton National Park, which was established in 1997. Nowadays Lake Kis-Balaton is a water protection system that contains a reservoir, a grove (mostly wetland with reeds) and a planned reservoir (Fig. 2).

Historical background

In the mid 18th century two large open water lakes were situated near the villages of Zalavár and Mekenye, indicating the previous greater extent of Lake Balaton. From when do the first records about Kis-Balaton date? The question is not difficult to answer if we look at old maps of the area. In the map of József Beszédes from 1833, the gulf was called Kis-Balaton, which was between the villages of Fenék and Hidvég, but on another map from 1836 by Hertelendy and Szalás, a little open water was marked behind the settlement of Hidvég, which had been separated by two huge wetlands from the water of the gulf.

The biggest river in the region is the Zala River, which carries 45% of the water transport for Lake Balaton. The river had had many meanders and very often changed its course in the wide valley. Thus its flood area had been swampy wetland with forests, shrubs and fields. When the Zala River had a small flow it disappeared in the wetlands, and at the same time smaller or larger lakes and tributaries branched out in other places. It did not flow faster after either snow melting or heavy rainfall, because it was hindered in speed by the rich vegetation, which also filtered its water. The erosion caused by the rain and slope moving were insignificant at this time, as the area had extensive woodlands that had fixed the soil and evened out the runoff of rainfall on the slopes. Great changes had taken place in the life of the people and the natural environment in the years of the Turkish era. The population had increased, and therefore it had needed more fertile land, which was obtained mainly by deforestation. A bigger problem was that the lords had cut down much of the woodland to produce potash (which contains K_2CO_3) for profit in the mid 1770's. Thus the processes of erosion had accelerated on the slope of the deforested hills, and the transported wash had deposited on the valley of the unregulated Zala River. [6]

In 1829 the Zala Water Regulation Company was established to regulate the river. The drainage of swamps between the villages of Hidvég and Kehida had been started in 1836, but it was not completed until 1895. The artificial bed of the river had become relative narrow, so that the river sediments had been carried further by the faster river, and it was not deposited there. During and after the works, the part of Kis-Balaton behind Hidvég was filled with silt.

The development of Kis-Balaton was also affected by Lake Balaton. A good example was the building of the railway in the region. The railway on the southern shore of Lake Balaton in Somogy County had been started in 1858 and had been destroyed by ice sheets in a northern windstorm in the winter of 1862, and therefore the railway company had been arguing for the reduction of the water level of Lake Balaton. The Sió sluice and canal was opened on 25th October 1863, and as a result of this the water level of the lake was decreased to one meter lower than the present surface of Lake Balaton (104.3 m). As a consequence, the water level of Kis-Balaton also fell by approximately one meter. If we look at the maps from 1836 and 1896 we can see that the area of Kis-Balaton had decreased considerably over 60 years, and its original territory had become marshland. In 1922 the Kis-Balaton Drainage Company was founded. Kis-Balaton was cut in two by a regulated deep canal with dykes which is now called the Zala River. Below the dykes, sluices were built in the deeper places, and these worked as follows: in the case of flooding the sluices were closed, but if the river had low water they were opened to allow water to flow from Kis-Balaton.

In the 1940's only two small lakes with shrinking areas, Lake Zalavár and Vörs, remained; they were completely covered by reeds, sedge and rushes. Except for some floods, Kis-Balaton only received water from rainfall, and it sometimes dried out entirely. The reinundation of the area was discussed in 1947, but it has not yet been carried out. On the contrary, the wetlands between the settlement of Hévíz and Kis-Balaton had begun to be drained. The old canals were widened, new ones were dug, and ferroconcrete sluices were built. This was a gradual way of causing desiccation and extinction over an ever increasing wetland. In the 1960's some problems were caused by sediments and plant nutrients that were transported along the Zala River into the Bay of Keszthely in Lake Balaton. For the solution of these problems, new plans have been established, and the 1980s was the beginning of the era of reservoirs on Kis-Balaton [6].

The water protection system

According to the plans, the old bed of Lake Balaton and the old wetlands will be re-flooded by the Zala River and its tributaries. With the reappearance of an open water body, the plant nutrients will be fixed by algae, by swamp plants on the water and by other aquatic organisms under water on the submerged plants. As a result, most nutrients will be not able to enter Lake Balaton.

For financial reasons, the building is taking place in two cycles. The western part of the protection system of Hidvég (Lake Hidvégi) was built from 1981 to 1987. On this part of the system, 18 km^{2}of open water appeared after the reflooding. The build-up of the planned bigger (54 km^2) eastern part of the protection system (Lake Fenéki) was started in 1984, but is still continuing. At the end of 1992 the northern part of the planned second reservoir (Ingói Grove has an area of 16 km^2) has been flooded temporarily because of the long period of construction and in the interest of reducing the algae level in the water, the first reservoir to be filtered by plants of the wetland. Here it has not been possible to build an expensive and permanent facility, and therefore the water level is ensured by a spillover.

Dessication has been reversed by the reappearance of water, but willow shrubs were eliminated, which indicated the last stage of swamp succession, and sedges also became extinct. Flooded areas are bordered by dykes, and thus there are not optimal condition for succession processes. Because of the claims of the nature protection authorities and the better water quality of the Zala River, the new plans suggested the eastern basin be divided into two parts. The flooded area of 16 km^2 would be separated from the whole system and would function during a flood, and its water level would be determined by nature conservation needs. Other reservoirs would work constantly, although the baffle dam is penetrable for water through three sites, and thus a concentrated current zone will not arise [9].

The build-up of reservoirs has had four basic purposes. Firstly the floating elements transported by the Zala River are fixed; secondly the organic materials are decayed; thirdly the plant nutrients (mainly nitrogenous and phosphorous forms) are kept in check. It also has a nature conservation function. The first and second tasks are mostly achieved by reservoir I, but the third and fourth tasks are achieved by the protection of vegetation, mainly the reeds [15].

Nature conservation

The area is under the protection of numerous international conventions such as Ramsar (1979), Bonn (1986), Bern (1990), Biodiversity – Rio (1992) and EU Directives on Habitats. It is home to numerous endangered species, for example the white-tailed eagle (*Haliaeetus albicilla*), the glacial relictum Siberian irises (*Iris sibirica*) and the endemic Hungarian pea (*Lathyrus pannonicus*). There are big populations of white water-lily (*Nymphaea alba*), cancer scissors (*Stratoides alloides*), water violets (*Hottonia palustris*), great egrets (*Egretta alba*), common coots (*Fulicata atra*), water spiders (*Argyroneta aquatica*) etc. [14].

Mistakes of the system

If the higher-level vegetation disappears, then planktonic eutrophication will be dominant. In this type of water there will be nitrogen fixing blue-green algae or cyanobacteria such as *Mycrocistis aeruginosa* and *Cylindropermopsis raciborskii*, which produce toxins. Research has shown that the growth and spread of other algae and more developed plants are blocked by these cytotoxins.

The protection of wetland-swamp vegetation and reeds is also deemed desirable for achieving the criteria of preserving biodiversity. The reed (*Phragmites australis*) is a terrestrial and wetland plant that only lives permanently in standing water and at a maximum depth of 1.8 m. In Lake Hidvégi, macrophyte (higher-level) vegetation has disappeared. With the increasing in the retention time of water (34 days), the nitrogen is run off by de-nitriphication, thus creating good conditions for the spread of blue-green algae. Thus in the lake the removal of nitrogenous forms is successful, although the efficiency of the removal of phosphorous forms decreased from 50% to 20% between 1986 and 1996. This was caused by the destruction of the reed beds, and also because the average depth of the reservoir is 1.1 m, which can be stirred up by wind speeds of up to 30 km/h, and thus the already dead and sedentary algae with phosphorous and nitrogenous forms in them are able to rise to the surface of the water again in order to be transported.

Along this section of the shore of Kis-Balaton, the zonation of plant communities has been stopped by the building of the Zalavár dam in Ingói Grove. The loss of macrophytes has been observed in 5–7 km^2 patches in the Ingói Grove (see the figure 3 at the end of the article, which is based on the air photos). The loss is caused by current and algal toxins combined. The toxicity is also shown by the original and planted woody plants well. The Ingói Grove is an overflow lake where there is a spillover (a dam with a fixed threshold), which means that the retention time is determined by discharge only, so the overflow level of the water is regulated, and nothing else. Unfortunately the «Revision of the Upper Reservoir of Kis-Balaton» summary report from 1997 suggests the repeating or interpretation of Lake Hidvégi to another planned part of Kis-Balaton too, the model system for which is Ingói Grove [17].

Conclusions

As a result of the recent research, we can make statements to avoid the rapid rise in water level and to allow plants enough time for adaptation. Due to the gradual rise in the water level, a typical swamp could have been formed, decreasing the chance for planktonic eutrophication. However the gradual rise in the water level has very important criteria, which is the appropriate control of water. Ecologist Béla Csányi said: «We can state that the planning and building of protection systems for Kis-Balaton have not managed to establish the circumstances for the efficient control of water [2].»

Therefore the following management activities are acceptable: the planting of reed, gradual flooding so that a low water level is ensured, good control of water, as well as continuous measuring and monitoring to follow the impacts of interventions.

These conditions have existed for 20 years. The Ministry of Environment and Water promises to complete the building of the system between 2007 and 2009. The Ministry claims that a new artificial canal will not be built, and the old habitats will be revitalised. The preparation of the program (519 million forints) will be financed by the National Development Office (75%), but the whole project costs 7.6 billion forints (about 30 million euros).

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The water quality of the Pécsi-víz 1996–2005

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Abstract
This study reveals the main water quality trends of the Pécsi-víz over the past 10 years, focusing on the effect of the city of Pécs, particularly the impact of the former mining site and stormwater runoff. The European Water Framework Directive requires a more complex approach to water quality analysis, and thus the improved monitoring and evaluation of data is an unavoidable task for the future. Our paper follows this issue and analyses the oxygen, nitrogen and phosphorus budget, as well as the microbiological properties, micropollutants, toxicity and other characteristics of the Pécsi-víz. Based on this examination we recommend intervention to avoid the deterioration of water quality.

Keywords: Surface water quality analysis, water quality trends, non-point contamination, point source pollution, monitoring, Water Framework Directive

Introduction
The Pécsi-víz Stream is one of the streams that in recent decades has been considerably affected by the intense social and industrial activities taking place in Hungary. The Pécsi-víz is located in the watershed of the River Drava. The natural environment of the Pécsi-víz has now been completely changed; its hydrological properties and water quality have been affected by human factors. These changes have been preserved in its sediments, which are deposited in the floodplain. When Hungary joined the European Union, new environmental regulations came into effect. The Water Framework Directive (WFD) launched by the European Union requires the re-analysis of the water quality of the Pécsi-víz. The project also aims to achieve the localization of contamination sources and offer possible recommendations for water quality improvement. The WFD further studies the favourable and unfavourable processes affecting the Pécsi-víz over the past decade (1996 to 2005), in order to establish the main principles for remediation.

Methods and materials
The water quality of the Pécsi-víz has been monitored since 1968 by the Southern Transdanubian Environmental and Hydrological Agency as an integral part of a nationwide water management program. The first water samples were taken at a single location: at Kémes (Southern Baranya County 2+100 km river-km), on a public bridge between the villages of Kémes and Cún. Samples have also been taken since 1969 further upstream, at Pellérd (public bridge on the outskirts of

Pécs. 39+005 river-km). In 1988 a new sampling site was assigned: at Tüskésrét Road, Tüskésrét, Pécs, 45+991 river-km), while samples have been taken at Zók (Zók Canal, 31+664 river-km) since 1995. Samples are taken every two weeks, and samples are analyzed either regularly or intermittently on a monthly basis. Samples are taken and maximum allowed concentrations are evaluated in accordance with the MSZ 12749 Hungarian National Standards.

Table 1: Measured water quality parameters based on the MSZ 12749 regulations (* Intermittently analyzed parameters).

Water parameter	Unit	Water parameter	Unit
Group A: Characteristics of the oxygen budget		**Group D: Microcontaminants and toxicity**	
Dissolved oxygen	mg/l	Phenols	µg/l
Oxygen saturation	%	Anionactive detergents	µg/l
Biological oxygen demand (BOI_5)	mg/l	Nonionic detergents	µg/l
Chemical oxygen demand (KOI_{ps})	mg/l	Petroleum products	µg/l
Chemical oxygen demand (KOI_k)	mg/l	Total Beta activity	Bq/l
Total organic carbon (TOC)	mg/l	*Aluminum	µg/l
Saprobity (Pantle-Buck) index		*Zink	µg/l
Group B: characteristics of the nitrogen and phosphorus budgets		*Mercury	µg/l
Ammonium ($NH_4^+ - N$)	mg/l	*Cadmium	µg/l
Nitrite ($NO_2^- - N$)	mg/l	*Chromium	µg/l
Nitrate ($NO_3^- - N$)	mg/l	*Nickel	µg/l
Organic nitrogen	mg/l	*Lead	µg/l
Total phosphorus	µg/l	*Copper	µg/l
Ortophosphate ($PO_4^{3-} - P$)	µg/l	**Group E: other characteristics**	
a-chlorophyll	µg/l	pH	
Group B: microbiological properties		Electric conductivity (at 20 °C)	µS/cm
Coliform bacteria number	1/ml	*Iron	mg/l
*Fecal coliform bacteria number	1/ml	*Manganese	mg/l
*Salmonella number	1/liter		

In addition to the parameters indicated in Table 1, the concentrations of all suspended materials, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} and Cl^-, are determined. Long-term data would depict more dramatic changes; during the period of centralized political rule in Hungary, when contamination was more considerable than today, measurements were taken much less often, and thus there is insufficient data on that period. In order to detect the sources of the contamination, we considered the seasonal changes in contaminant concentrations and the principles of the MSZ 12749 regulations. In a group of contaminants, if any of the group members reaches the highest concentration of the given contaminant, then the entire group will be listed in that category. Based on these concentration data, we determined the contamination sources as well as their spatial distribution.

After sampling, samples were stored in either 1-liter polyethylene or glass bottles that were heat sterilized before sampling. Samples were stored at 4°C before analysis. Titrimetry was used to determine methyl-orange and phenophtalein alkalinity, Ca^{2+}, Mg^{2+}, total nitrogen, S^{2-}, KOI, BOI and dissolved oxygen concentrations. Sedimentation based on Stokes Law was used to determine total suspended material and the total dissolved material concentration. We used a digital pH meter to determine pH, and conductivity was measured with a conductivity meter. Photometry was used to measure nitrite, nitrate, ammonium, phosphate, cyanide, petroleum, ANA detergent and chlorophyll-a concentrations. An atom adsorption spectrophotometer was used to measure metal concentrations. Herbicides (phosphoric acid based), PAHs, PCBs, chlorobenzenes, benzenes and their residuals were determined using gas chromatography.

The Pécsi-víz stream belongs to the Drava River Basin. The source of the stream is located in the city of Pécs and flows into the Drava River. The Pécsi-víz runs down the Pécs plain and Drava floodplain, passing through 19 settlements with a population of 170,000. The stream is 59.6 km long, and the watershed has an area of 603 km^2. The cross section profile, the stream bed and the bank are artificial. The ecohydrological conditions of the stream are heavily affected by human activities. The mean long-term discharge of the stream is 2 $m^3 s^{-1}$, and at the mouth of the stream the highest discharge is 14.8 $m^3 s^{-1}$. The range of fluctuation of water level is around 2 meters.

The watercourse of the Pécsi-víz is divided into two sections. The upper section is located in the built-up areas of Pécs (140 km^2), and rest of the stream passes through the mostly agricultural lands of Baranya County. These differences are reflected in both the morphology and water quality of the stream. The water quality of the upstream section of the Pécsi-víz greatly depends on the former waste heap of the coal and uranium mining district, and is strongly influenced by the anthropogenic effects of urbanization and industrialization. The downstream section of the Pécsi-víz was transformed for agricultural use.

The water quality of the Pécsi-víz is greatly affected by human impacts around its source [1]. The geo-environmental setting of the watershed was considerably changed by open-pit mining (terminated in 2004) and underground coal mining. The environmental properties and the intensity of the hydrologic cycle were also impacted by the change in the area's relief features [1]. The main branches of the Pécsi-víz are fed by springs originating from karstic underground water, where the limestone aquifers are dissected at an elevation of 400 m [2]. Following the confluence of the Szabolcsi Stream and the Meszesi Stream, the Pécsi-víz has several tributaries to the west (the right side of the stream), flowing downhill on the southern slopes of the Mecsek Mountains, while it almost completely lacks tributaries along its left bank. The hydrological properties of the tributaries have been strongly impacted by local coal mining, due to the presence of waste heaps, open-pits and waste piles functioning as valley dams. Slurry pools deposited as by-products of the formerly coal-based power plant further contaminate the water of the Pécsi-víz, as rainfall infiltrates through the muddy deposits. The area of the slurry pools belongs to the floodplain of the Pécsi-víz; however, the area has been filled up with various sediments since the second half of the 19th century. Later a railway station and an industrial park were created in this swampy area; its industrial characteristics are still present. Here, over the past decades, the slaughtery, the leather and porcelain factories have been the main sources of contamination. The petrol distribution center on the western margin of Pécs has also significantly affected the health of the local environment. The sewage system also conveys its load into the Pécsi-víz. Water quality is also affected by the legacy of uranium mining, communal point sources and non-point agricultural activities.

Results and discussion

Main characteristics of the oxygen budget of the Pécsi-víz

The dissolved oxygen concentration (DOC) of the Pécsi-víz over the studied period ranged between 2.34 mg/L (at Zók) and 12.23 mg/L (at Tüskésrét). The highest values were measured at Tüskésrét, where water quality had category number I. (highest) in each year over the past decade. A slowly increasing oxygen tendency has been observed at each sampling station over the past decade, and water quality reached at least category 3 (category 1 being the best) in each location. Biochemical water demand (BOI5) indicates the self-straining capacity of a stream. In the case of this parameter, the eater quality of the Pécsi-víz was as poor as category 5. The extremely high concentration anomaly detected during fall 2001 was presumably due to organic contamination. Due to the gradual but continuous quality improvement, water quality reached category 1 by 2005. Water oxygen budget can be also characterized by KOI_{ps} and KOI_k parameters. The most extreme values of these were measured at Tüskésrét, where maximum values exceed the allowed limits severalfold. Concentrations higher than 15 mg/L have not been measured over the past two years (with the exception of Zók, in spring 2004), and the overall quality fell into category 3.

The total dissolved organic carbon concentration (TOC) had two maximum peaks, measured during fall 2001 and spring 2003. Water quality was category 5 in 2001 and 2003. Apart from these anomalies, the Pécsi-víz fell into category 3. The saprobithy index is the rate of decomposition of dead organic material. The most unfavoured values were measured at Zók (category 4 and 5 values). A slow but steady improvement has been observed regarding this water quality parameter; with the exception of Zók, the overall water quality is category 3 in this respect. The oxygen budget of a freshwater system is mainly influenced by the total organic material content. [3]. In the case of the Pécsi-víz such contamination is the result of the insufficient straining of industrial and communal waste water. The worst water qualities were taken at Zók, where the water is most heavily loaded by the local sewage plant and by the infiltrates of the former uranium mine.

Characteristics of the nitrogen and phosphorus budgets

These parameters depict the nutrient budget of a water system. The 3-month average values of the NH_4^+ ion ranged between 0.04 (Tüskésrét) to 18.38 (Zók) mg/l over the past decade. It is notable that NH_4^+ concentrations are higher during the winter than in the summer. The lowest NH_4^+ concentrations were measured at the Tüskésrét site, where water quality is category 3. Water quality in respect of NH_4^+ concentrations was worse at the other three sampling sites; at these locations water quality only reached category 5. The highest NH_4^+ concentrations were measured in summer 2003; since then, with the exception of Zók, concentrations have decreased. Nitrate (NO_3^-) concentrations ranged broadly in the studied period. NO_3^- is produced either spontaneously as a result of decomposition processes or as an end-product of nitrification. Overfertilization and subsequent leaching from soils is also an additional NO_3^- source [4]. The highest NO_3^- concentrations were measured at the Tüskésrét site; concentrations decreased further downstream towards Zók. A second NO_3^- peak was detected at Kémes, explained by the poor oxygen supply there. NO_3^- concentration decreased over the winter and reached its peak during the springs and summers, when more fertilizers were applied to the soil. Leaching of NO_3^- is also affected by the amount of precipitation and rainfall intensity. Intense leaching was observed after fertilizer applications followed by heavy rainfalls or intense snowmelt. Summer flash floods also carried a substantial amount of NO_3^- [5]. Regarding NO_3^- concentrations, water quality was category 4 at Tüskésrét, Kémes and Zók, and varied between category 4 and 5 at Pellérd. NO_3^- concentrations decreased over the past two years; today water quality in respect of NO_3^- is category 3 along the entire length of the Pécsi-víz. Nitrite (NO_2^-) concentrations varied between 0.16 (Tüskésrét) to 3.55 mg/L (Zók) over the period studied. Regarding the lowest NO_2^- concentrations, water quality is category 3, however, and with the exception of Tüskésérét, NO_2^- concentrations frequently exceed the permitted maximum, and thus water quality falls into category 5 and is regarded as heavily contaminated. The seasonal changes are similar to the seasonal changes in NO_3^-, but more NO_2^- peaks were observed over the investigated period than NO_3^- peaks. The decomposition of organic matter is intense over the summer, although due to the lack of oxygen availability NO_3^- concentration increases more rapidly than NO_3^-. Nitrite is a prime indicator of new direct organic contamination, although due to the self straining capabilities of streams, NO_2^- is oxidized, and thus the concentration of other nitrogen compounds increases [5]. Organic nitrogen rapidly decomposes to inorganic form, primarily to ammonium (NH_4^+). The most extreme nitrogen peak was observed in summer 2003 as a result of the failure of the aerating pool at the communal sewage plant. Due to this failure, the nitrogen level of the stream increased severalfold.

Phosphorus concentrations in natural surface waters is generally low, although it is important to monitor it, as it is one of the minimum factors in point-originated organic matter production. Phosphorus concentrations at the four sampling sites varied widely. At the first two upstream samplings sites (Tüskésrét and Pellérd), water quality is category 3 in this respect. Here, polyphosphates are discharged into the water when sewage is heavily loaded with synthetic detergents. Subsequently, polyphosphates are slowly hydrolyzed into orthophosphates. [5] At the other two downstream sampling sites (Zók and Kémes), the measured phosphorus concentrations exceeded the allowed 1000 μg/l maximum value. Here water is considered to be category 5, i.e. heavily contaminated, in respect to phosphorus concentration. The high phosphorus concentration here is likely caused by the intense tillage and agricultural activities. Similarly to the nitrate, winter phosphorus concentrations in the water are lower than the summer concentrations, which is likely caused by the seasonal difference in fertilizer application. The temporal changes in orthophosphate concentrations are very similar to those observed in the case of phosphorus. The amount of chlorophyll–a refers to trophic intensity. Here seasonal changes are clearly noticeable. As in the case of nitrogen, the failure of the aeration pool in the summer of 2003 is clearly indicated in the concentration diagrams.

Upstream along the Pécsi-víz, the environmental load and contamination level is primarily determined by the sewage plants of Pécs and Pellérd and by the leather factory. Although the volume of discharged sewage from the leather factory has decreased recently, this company is still a significant ammonium emitter along the entire course of the Pécsi-víz. On the downstream stretches of the river, incorrect treatment of fertilizers as well as overfertilization has caused considerable problems. As a result, nitrogen and phosphorus concentrations exceed the permitted maximums severalfold.

Microbiological characteristics of the Pécsi-víz

No contamination of microbiological origin was observed along the Pécsi-víz over the past decade. This is a considerable improvement, since on the basis of the 1990–1996 measurements the Pécsi-víz suffered from heavy microbiological contamination.

Microcontaminants and toxicity

Inorganic microcontaminants The most important inorganic microcontaminants are metals, especially toxic heavy metals. Suspended material can be rich in toxic heavy metals, and thus it deposits on the riverbed according to Stokes Law, and under appropriate circumstances it can re-enter the watercourse and subsequently jeopardize the living organisms in the river. Aluminium concentrations varied widely over the studied period. Two seasonal maximums were observed, both at the Tüskésrét sampling site. Here, in the heavily urbanized region, the contamination load was directly unloaded to the water. Due to the disappearance of surface application technologies, the river's Al_{3+} load decreased. Most of the point sources are located in Pécs today, at a reasonable distance from the water course. In addition to the two seasonal Al_{3+} maximums, water quality is category 3, i.e. medium quality, with some improvement over the past two years.

Zink levels were relatively low over the studied period, and never exceeded the 75 μg/l permitted maximum concentration. As a result, water quality is considered category 2 in this respect. Mercury concentration peaks were observed at Tüskésrét, which is most likely caused by the metal content of the power plant's leechate. The highest cadmium concentration (3.36 μg/l) was measured at Tüskésrét. However, apart from these peaks, Cd concentrations were low and relatively constant over the studied period, and have been continuously decreasing since 1999.

Chromium concentrations were extremely high at the beginning of the studied period, but contamination levels have decreased considerably since the second half of 1997. Cr concentrations measured over the first year and a half of the studied period exceeded severalfold the maximum allowed 100 μg/l concentrations, i.e. water quality fell into category 5 in this respect. Between the second half of 1997 and the second half of 2002, Cr concentration occasionally exceeded 10 μg/l, and was thus categorized as category 2. From 2003 on, the measured Cr concentration has been below 10 μg/l, and thus water quality reached category 1. The Cr load of the Pécsi-víz most likely originated from the local leather factory as a point-source contaminator. However, due to the decline in processed leather production and the modernization of filtration systems, the Cr contamination of the Pécsi-víz decreased considerably.

Nickel (Ni) concentration fluctuated to a great extent at the Tüskésrét Site, while water quality was category 1 at the other three measuring sites. Chromium concentrations were greatly affected by industrial processes at Tüskésrét, but here water quality has also been category 1 over the past two years. Industrial origin lead (Pb) concentration peaks were measured twice over the studied period. These two peaks were detected at all sampling sites, although the highest values were once again measured at Tüskésrét. The first Pb peak was measured in winter 1997, and the other maximum was detected in spring 1998, when the water quality of the Pécsi-víz fell into category 3. Water quality was category 1 and 2 at the other three sampling sites. Copper concentrations have fluctuated greatly at all sampling sites during the studied period, but water quality remained category 1 in this respect throughout the entire period. In summary, regarding the metal concentrations of the Pécsi-víz, water quality was category 1 with the exception of Al^{3+}.

Organic microcontaminants

The most common organic microcontaminants are the phenols, anionactive detergents and petroleum. Their concentrations in the Pécsi-víz fluctuates greatly. The Pécs Coke Processing Plant formerly produced a considerable amount of phenol during the course of processing. The hydrocarbon concentrations of the Pécsi-víz have shown a decreasing tendency during the second half of the studied period. On average, water quality in this respect was category 3, but in 2005 water quality only reached category 4 and 5 at Zók. The anionactive detergents change the surface tension of the water, which is visible in the form of foams. The foams prevent oxygen from entering the water and are esthetically undesirable. Its concentration often exceeded 500 mg/l, at which point water quality was considered category 5. The highest concentration was detected at Zók, where the spring 2003 averages reached 1492.77 μg/l. A detergent concentration of only 705.66 μg/l was measured at Kémes at the same time, indicating the downstream dilution of the contamination. The peak of the contamination was caused by the failure of the sewage plant's aeration pool, i.e. communal sewage was discharged to the stream. Due to the modernization of the sewage system and the improved treatment of communal sewage, water quality has been category 1 since 2005. Due to their widespread application of petroleum compounds, such contamination frequently occurred in the Pécsi-víz. As petroleum compounds have a lower density than water, they float on the water's surface. Floating hydrocarbons not only deteriorate the esthetic value of the water but are also harmful for wildlife, as floating hydrocarbons hinder oxygen diffusion to the water. Petroleum concentration has always exceeded the permitted maximum value of 250 μg/l, and thus water quality is considered category 5. Over the past two years, however, some improvement has been detected, and thus water quality was upgraded to category 4. The highest petroleum concentrations over the past decade were measured at Pellérd, which was caused by the presence of petroleum tanks at a petroleum distribution hub, and obviously the diffuse non-point petroleum sources of Pécs. Due to the improper drainage system in Pécs, a significant amount of petroleum is leached into the subsurface following intense rainfall events. Formerly, groundwater was heavily contaminated with petroleum compounds in the vicinity of mining areas and open-pit mines, although most of these areas have been efficiently decontaminated over recent years.

Radioactive materials
Radioactive materials are extremely harmful contaminants as they can cause irreversible health damages to humans. All beta-activities have been closely monitored in the Pécsi-víz, especially focusing on $_{137}Cs$ and $_{90}Sr$. No radionuclides and radioactive material are dissolved in the water, although the river sediments do contain some. Sediments contain three to five times more radioactive materials than the average in the crust; however, according to the research, this value is not extreme and can be attributed to the geological characteristics of the area [3].

Other characteristics
Over the past decade, the measured ph values of the Pécsi-víz have always been higher than pH 7, but never exceeded pH 8.5. Specific electric conductivity (i.e. the electrolyte concentration of the water), with the exception of Tüskésrét, has decreased over the past 10-year period. The lowest EC values were measured at Kémes in spring 2005, while the highest values were detected in fall 2004 at Tüskésrét. Despite the termination of active mining in the area by 2000, leechates originating from the reclaimed tailings still provided an additional electrolyte load for the Pécsi-víz. Electrolyte concentration was further increased by the slurry pools of the Power Plant. In respect of EC, water quality of the Pécsi-víz is category 4. Regarding the iron (Fe) content of the Pécsi-víz it is category 2, and was upgraded to category 1 over the past two years. Manganese (Mn) concentrations have generally been high, and water quality has mostly been category 4 in this respect, with the exception of Tüskésrét, where quality fell into category 5. However, a slight decrease in Mn concentrations was also observed at Tüskésrét by the end of the studied period. One maximum peak was detected at Zók in spring 2000, likely caused by the leechates from the uranium tailings. The average high manganese concentration of the water has a geologic origin. The most common contaminator of the water is suspended material of communal or industrial origin. Suspended material primarily originates from communal sewage as well as sewage from the porcelain factory and ore processing plant. Point sources of suspended materials are primarily located in Pécs, as the highest concentrations were measured at Tüskésrét and Pellérd. Following the construction of the modern straining system at the porcelain factory, the suspended material load of the Pécsi-víz decreased dramatically.

Potassium and sodium ions primarily originate from rocks and soils. Potassium concentration has usually been highest at Zók. Potassium contamination most likely originates from the leechate of the uranium tailings. By the time the water reaches Kémes, potassium concentration decreases due to dilution, but is still higher than average. Total hardness has usually been highest at Tüskésérét, where the Pécsi-víz flows through rocks with high carbonate content.

The primary source of sulfate ions (SO_4^{2-}) was the former coal mining. Formerly, the partial dissolution of the slurry at the power plant further increased the SO_4^{2-} concentration of the Pécsi-víz. Chlorine concentration was exceptionally high at Pellérd, where sewage was disinfected and sterilized with Cl^-.

Conclusions

The water quality and contamination levels of the Pécsi-víz accurately reflect the post-communist structural reconstruction of industrial activities in Hungary alongside the more environmental-conscious policies of the country. The decrease in microcontaminants, suspended material and EC supplied by point sources of industrial origin has been considerable over the past decade and a half. Sewage straining systems were modernized, allowing for more efficient cleaning of communal and industrial waste water. Due to the closure of the large industries of the communist period, in many cases we have recently been unable to detect point source contaminators. The diffuse non-source contaminations are likely explained by small companies established after 1990. In many cases these companies struggle with financial problems, and thus cannot fulfil the relevant environmental standards. Rainwater managements is also insufficient in Pécs. Due to the high coverage of sealed surfaces, surface runoff washes a large sediment mass into surface waters. Such problems could be solved with appropriate stormwater management and storage and through the establishment of adequate water reservoir systems. Additionally, decreased surface runoff would moderate the contaminant load of surface waters. Illegal waste depositions, sewage dehydratation, and other agricultural and industrial contaminations are decreasing, yet still contribute to excess environmental load. By leaching such waste deposits, various ions, heavy metals, hydrocarbons and non-decaying organic materials are introduced into our surface waters, reducing water quality.

In summary, the contamination of the Pécsi-víz reached a critical level over recent decades. As a consequence of the heavy contamination load, oxygen supply was minimal in many cases, and thus the Pécsi-víz is unsuitable for any type of water utilization. The maintenance of the present land use activities is insufficient to fulfill the requirements of the Water Framework Directive. The following steps need to be taken in order to change and improve the environmental qualities in the catchment area of the Pécsi-víz: 1): management of the leechates of the reclaimed mine tailings and slurry pools; 2) better information concerning the industrial activities of small and medium-sized companies and their intermittent investigation. 3) management and prevention of surface runoff and the subsequent downwash of contaminants; 4) knowledge of the exact location of point-source contaminators; 5) more reasonable fertilizer, insecticide, pesticide, and fungicide application; 6) establishment of a modern sewage system with appropriate sewage straining; 7) creation of buffer zones; 8) eco-remediation.

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Water management in a tourism-oriented Mediterranean town: the case of Alghero, Sardinia

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Abstract
The paper focuses on the relationship between tourist development and water availability in the town of Alghero (Sardinia). Seasonality is considered to be a key factor in water shortage. The need for sustainable water management is pointed out, and an experimental policy based on higher water prices in exchange for higher quality service is presented.

Keywords: Water resources, water policy, sustainable water use, tourism, Mediterranean region, Sardinia, Alghero

Introduction
The availability of the right quantity and quality of water is a fundamental factor in tourist development. An environment rich in water holds great appeal for tourism. At the same time, however, tourism can put heavy pressure on water, and can contribute to the degradation of this essential resource. In water-deficient areas of the globe, water availability is a very important constraint on all forms of resource use. Yet despite its intrinsic importance, water often appears to be viewed as a non-critical factor in the location and scale of tourism development. This can lead to conflicts when new demands are made on scarce water resources for uses such as tourism, which are seen as non-essential. This is particularly frequent when plans for tourism development take place in island environments.

At different scales, tourism initiatives are often seen as threats to established claims on water resources. The question of how to deal with emerging claims on water resources for tourism is an important concern in the management of tourist resorts.

The aim of this paper is to show new trends in water policy in a typical Mediterranean tourist destination: Alghero. This town is located in North-Western Sardinia and is an example of a seaside settlement with a tourism-oriented economy. Because of the climatic conditions of the area, water scarcity is worsened by heavy consumption caused by the relatively recent tourist development. Possible conflicts for the use of water have become more and more likely, and new water policies are under experimentation in order to avoid these conflicts and reduce unsustainable use.

Figure 1: Map of Sardinia / www.graphicmaps.com

A survey performed by the University of Cagliari showing the links between lifestyles, water prices and consumption seems to be particularly interesting as a first attempt to define a new water policy in Alghero. The opinion of the local population is said to be a key factor in the adoption of new water-pricing policies, in order to keep consumption under control, to avoid potential conflicts and to cover the growing expenses connected with the water supply system. New tendencies towards higher prices for better water service seem to be taking place and will be presented in this paper.

The context

Alghero, situated at the North-Western tip of Sardinia, is the largest tourism-oriented town on the island, thanks to a wide range of natural and cultural attractions and to its proximity to the international airport of Fertilia and to the harbour of Porto Torres. Alghero, which was founded in 1102 by the Genoese Doria family, although the area had already been inhabited in prehistoric and Roman times, was one of the first towns conquered by the Aragonese Crown in Sardinia (1353), and was later resettled with Catalan colonists. The majority of its inhabitants still speak the Catalan language, a peculiarity that adds to the town's cultural significance and international renown.

Its picturesque old district, surrounded by walls and towers and bordered by the sea, is famed for its traditional coral and gold craftworks and lively atmosphere. Alghero is located near a string

Figure 2: View of Alghero

of white sand beaches, cliffs and wetlands (Calik) that leads to the bay of Porto Conte (Portus Nympharum in the Roman time) and to the 350 m high cliffs of Capo Caccia, also famous for the spectacular Neptune's Cave and for the rugged island of Foradada. The whole section of coastline is traditionally known as the «Coral Coast» thanks to the abundance of red corals. Most of the area is protected by two natural parks (Porto Conte - Capo Caccia and Capo Caccia - Isola Piana) established to preserve its spectacular scenery and the terrestrial and marine fauna and flora (griffon, flamingo, wild horse, deer, mouflon, turtle, red coral, posidonia). The proximity to the National Park of L'Asinara Island, the presence of important prehistoric and Roman archaeological sites and the high-quality wine and olive tree production enhance the varied tourist appeal of the Alghero area.

North-Western Sardinia is a typical Mediterranean area characterized by dry and hot summers and mild and rainy winters. The average temperature in January is 9°C, in July 24°C, and the average rainfall is 583 mm per year, with a remarkable variability and a range that extends from 390 mm (recorded in 1981) to 831 mm (in 1966). July and August are often completely dry. Overall, the amount of precipitation seems to show a gradually decreasing tendency.

Even if North-Western Sardinia hosts the largest natural lake on the island (Baratz, 60 ha of surface and 2 Mm^3 of capacity) and several internationally important wetlands, the area suffers from a deep drought in the summer period, and all of its rivers and streams (Cuga, Càtala, Serra, Mattone, Càlvia, Barca, Filibertu, Oruni) show a torrent regime and are often completely dry between June and September. Irrigation, however, permits year-round agriculture in the Nurra plain, which was equipped in the fascist period and is still one of the richest agricultural districts in Sardinia.

Despite its attractiveness and growing international connections, the economic and demographic features of Alghero show an overall stagnation. Its population is stable around 38,000–40,000 inhabitants, with a tendency towards a slight decrease due to population ageing, the settling of retired people from other parts of Europe and the relocation of young families to neighbouring municipalities due to rising real estate prices. The whole Cuga Basin, which includes the watersheds of the local streams, hosts 57,000 inhabitants. The share of the town of Alghero has grown from 59% (1971) to 68% (2001) of the total population, which proves its role as a local economic centre. According to European Directive No. 60 (2000), water management should be organised on the «river basin» scale. In the case of Alghero, the watershed is identified in connection with the largest stream, called the «Rio Cuga». This paper, however, will mainly focus on the town itself, in order to describe its main features as a homogeneous tourist system and to focus on the water policies adopted or proposed by its municipal authorities. Its relevance as the only demographic and economic centre in the area justifies the choice to separate it from the rest of the Basin where necessary.

Alghero was one of the first municipalities in Sardinia to start an Agenda 21 programme, which has already reached an advanced stage with the activation of the civic forums in 2003 [2].

The main features of tourism on the «Coral coast»

Alghero is the oldest international tourist destination in Sardinia. In 1954 a flight from and to London was established by tour operator Horizon Holidays [7]. At that time the town had only 2 hotels, and very few international tourists visited it, although a certain number of domestic tourists already used to spend holidays in Alghero. By the early 1960s the situation had changed completely, with some 2000 beds and almost 200,000 nights reached. In the same period, and for the first time in Sardinia, two public administrations were established in the city to promote the development of tourism (the Associazione turistica Pro Loco and the Azienda Autonoma di Soggiorno e Turismo) [8].

Now Alghero is one of the most important Sardinian tourist destinations. Various low-cost flights connect it with several European cities, and as a result international tourism is growing rapidly, with positive impacts for the economy of both the town and the surroundings. Domestic tourism is also well established, and the area is also popular witth day trippers. Statistics about tourism demand illustrate this trend (Fig. 3). In 2004, Alghero reached some 240,000 arrivals and almost 1 million nights.

Tourism supply consists of 11,000 beds in hotels and camp sites. Recently, 200 beds in tourist farms and bed and breakfasts have been added to the accommodation offer. Some 8300 second homes with about 38,500 beds complete Alghero's tourism supply [5]. This is a matter of concern for various reasons. Most second homes are situated along the coast, which poses a risk to the environment. Moreover, their position in the tourist system in mostly informal. As a consequence, the resulting revenues cannot be taxed, and tourism flux escapes the statistics.

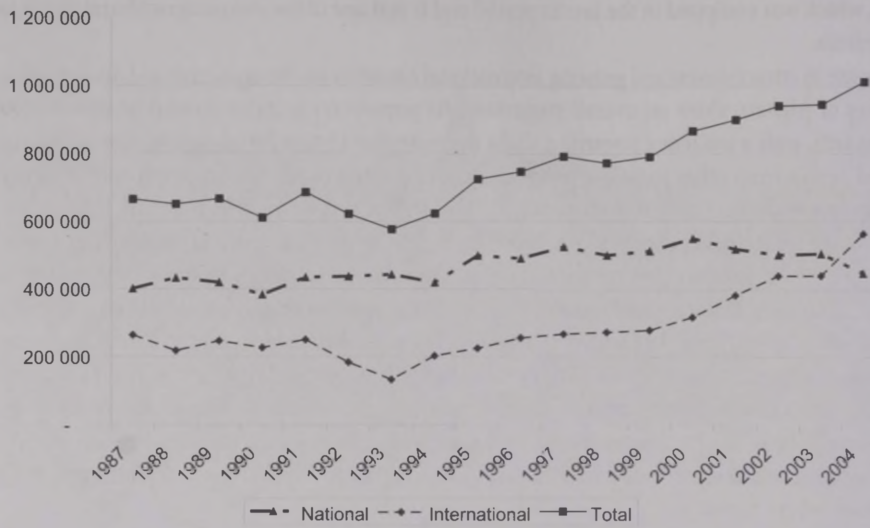

Figure 3: Number of tourist nights in Alghero (1987–2004)
Source: EPT (Ente Provinciale per il Turismo).

Seasonality is another matter of concern. Almost 60% of tourism demand is concentrated between June and September (Fig. 4). During peak periods, the population triples and a very heavy use of the territory and its resources arises. Both tourists and residents complain about traffic congestion, pollution, noise and the over-crowding of beaches [9]. The water shortage is one of the most serious problems resulting from seasonality. As Baum and Lundtorp point out, seasonality is assumed to be a problem in tourism because of its environmental and social effects, while little mention is made of that fact that it may not be wholly negative for tourist destinations [1].

Tourism, water users and water management

The growing importance of tourism has put increasing stress on local water resources. The weakness of the industrial and agricultural sectors has made it possible to avoid serious conflicts, but strict water restrictions in the summer months have become more and more common, especially in the driest years. In the summer of 2003, for example, a combination of low precipitation, high temperatures and intense consumption by domestic and tourist users led to a dramatic cut in water supply, which was delivered for only 6 hours a day (from 6 am to noon).

The town of Alghero, with its mixed and fluctuating population, purchases its water from the ESAF (Ente Sardo Acquedotti e Fognature), the Sardinian authority for aqueducts and sewers, which provides potable water to 2/3 of the population of the whole Sardinia. The ESAF manages an integrated hydraulic system that covers water collection and distribution, sewer systems and wastewater treatment in over half of the municipalities of Sardinia, including Alghero (the ESAF

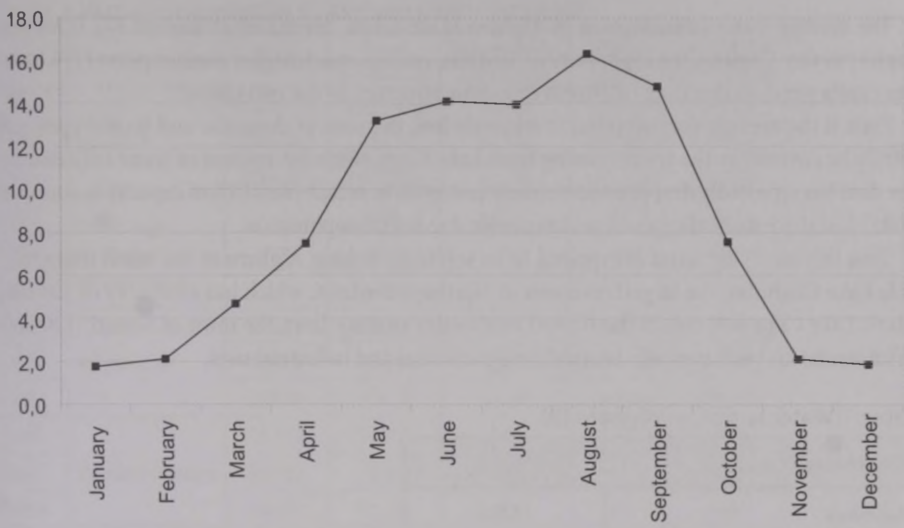

Figure 4: Seasonality of tourist arrivals in Alghero (in %, 2004)
Source: EPT (Ente Provinciale per il Turismo).

is currently being replaced by a Regional Consortium named «Abba Noa» (meaning «New Water» in the Sardinian language). The water provided to Alghero comes from Lake Cuga, a reservoir situated about 10 km North-East of the town, with a capacity of 25 000 million m^3, which is currently (August 2006) only half full. The water coming from the dam, which is increased by a small amount of water extracted from local aquifers, is treated in a purification plant and delivered to the urban population.

Lake Cuga, which is situated in a relatively dry area and surrounded by low hills lacking in real rivers, suffers from a high variability in its water level and from severe eutrophication, which sometimes threatens its use as a source of drinking water.

Alghero purchases an average of 11 to 13 Mm^3 of water every year. Only 3.3 Mm^3, however, are actually paid for by the users. If we also consider the remaining consumption, including some families and hotels served by tank trucks, the volume of water that is actually used is only 6.25 Mm^3. The rest, i.e. 53% of the 13 Mm^3 normally pumped into the town aqueduct, is thus lost through leakage.

The average amount of water supplied to the town of Alghero is basically stable year round, in spite of the considerable growth of its population in the summer period. The population served by the ESAF pipes grows from 45 000 people in the winter to 120 000 people in the summer months. The higher demand in the peak period makes the water pressure in the pipelines drop to lower levels, and leakage is consequently greatly reduced. In the low season, however, pressure is much higher and leakage is much more considerable.

The average water consumption in Alghero is moderate, estimated at around 372 litres per capita per day. Cagliari, the capital city of Sardinia, reaches much higher consumption (776 litres per capita per day) due to the different economic structure of the two towns.

Even if the average consumption is relatively low, the sum of domestic and tourist uses can hardly be covered by the water coming from Lake Cuga, since the amount of water collected by the dam has repeatedly dropped to extremely low levels in recent years (8% of capacity in summer 2003) and since its quality tends to deteriorate due to euthrophication.

Thus this worrying trend is expected to be solved by linking Alghero to the much more reliable Lake Coghinas, the largest reservoir in Northern Sardinia, which has a capacity of 224 000 Mm^3. Lake Cuga will collect the treated wastewater coming from the town of Sassari (120 000 inhabitants) and will basically be used for agricultural and industrial uses.

Table 1: Water supply in Alghero [9]

Households served by:	
Aqueduct	14,021
Wells	631
Tank trunks and other sources	117
Total*	14,574

* Some households are served by more than one system

In addition to the problem of water leaks, which is responsible for the loss of about half of the potable water pumped into the town's aqueduct, and besides the considerable change in pressure between the winter and summer months caused by the weight of tourist consumption, three other serious problems threaten and hamper the effective functioning of the water supply system:

1) the coexistence of several pipelines in the same street, due to different age of construction,

2) the clogging of the pipes caused by the presence of relatively highly calcareous groundwater mixed with the freshwater coming from Lake Cuga,

3) the daily reduction of water pressure carried out every night by the water authority in order to reduce losses, which puts greater stress on the infrastructure.

The ESAF also manages wastewater collection and treatment, which is currently able to cover the needs of both the local population (40 000 people per day) and tourists (60 000 people per day in the summer months). The villages of Fertilia, La Palma and Maristella have their own treatment plants for their local needs.

About 96% of water in Alghero is consumed by the civil sector (households, administration, trade, tourism, public uses), with the local population consuming up to 70% of water every year (Table 2). The table refers to the amounts of water actually paid for by the users. About 15% of the total is absent because it is not accounted for by the ESAF, and is basically distributed for free.

Table 2: Water consumption in Alghero (2001–2003) [9]

Year		Total	Local population	Non-resident population	Tourist sector	Agricolture and industry
2001	Total m^3	4,115,168	2,829,470	16,548	168,807	166,584
2002		3,767,047	2,616,545	25,340	170,148	168,893
2003		3,761,055	2,631,416	41,718	157,366	147,539
2001	Percentage on total consumption	-	70%	0%	4%	4%
2002			69%	1%	5%	4%
2003			69%	1%	4%	4%
2001	m^3 per user	296.52	262.66	56.67	3,836.52	352.29
2002		252.48	227.47	44.46	3,911.45	345.74
2003		234.60	215.32	44.48	3,983.95	295.97
2001	Number of users	13,878	10,772	292	44	473
2002		14,920	11,503	570	43	488
2003		16,031	12,221	938	39	498

Year		Public uses	Commercial and professional uses
2001	Total m^3	205,377	161,169
2002		189,751	124,666
2003		164,238	128,656
2001	Percentage on total consumption	5%	4%
2002		5%	3%
2003		4%	3%
2001	m^3 per user	1,649.61	122.66
2002		1,336.27	95.42
2003		1,160.69	94.57
2001	Number of users	124	1,314
2002		142	1,306
2003		141	1,360

New trends in water management: water pricing

One of the main issues in the new water policy supported by the European Union concerns the problem of cost recovery and water pricing. The price of water must be related to the amount of the resource taken from the environment and the level of pollution caused by its use. The price must be set in consideration of the different characteristics and impacts of the users (agriculture, households, power production, industry, tourism).

The main costs that must be considered when water price is set are:

- financial costs (supply, administration, functioning and maintenance), including the management of investments and profits; these correspond to long-term marginal costs;

- environmental costs (to repair the damages caused by water use);
- resource costs (the costs arising from unsustainable water use for other users, such as negative externalities and opportunity costs).

Water pricing for domestic use must consider the need for economic efficiency and social equity, as water is a necessary good, at least for basic levels of consumption. The best way to deal with this problem is to set different prices for different amounts of consumption, guaranteeing low prices for normal daily uses and setting high prices for other kinds of consumption, in order to boost water saving. As a consequence, a strict water consumption measurement system must obviously be established in order to identify the levels of consumption for each household or user.

In the following section, the first results of a survey carried out by the University of Cagliari, with the aim of determining the ideal price of water according to the wishes of the local population and the principles of Agenda 21, will be explained. Another aim of the study, which will be performed in a second stage, will try to determine how water prices can actually influence water consumption [9].

Higher prices have been proposed in exchange for higher water quality. The demand for water is often seen as extremely rigid and not easily influenced by price variations, since water is used for necessary purposes (drinking, cooking, personal and house hygiene). Nevertheless, different prices for different levels of consumption can fulfil both aims (economic efficiency and social equity).

According to the survey, which was addressed to a group of 405 households representative of the main socio-economic features of the population, the people of Algherese are of the opinion that the quality of tap water is quite bad, with over 63% of the people answering «quite bad» or «very bad», and only 1.5% saying it is «very good» (Table 3).

Table 3: Users' opinion of tap water quality in Alghero [9]

Opinion	Answers	Percentage
Very bad	89	22.0%
Quite bad	169	41.7%
Quite good	126	31.1%
Very good	6	1.5%
No answer	15	3.7%
Total	*405*	*100.0%*

About 10% of the people use public or private fountains, but the main source of drinkable water for the local people is mineral water, which is normally purchased by over 92% of the households (Table 4).

As an average, every household in Alghero buys 76.37 litres of mineral water per year, at a cost of € 22.20. Only 8.1% of the people actually drink the tap water, and most of these people also use mineral water.

Table 4: Alternative sources of water in Alghero [9]

Fountains	Answers	Percentage	Mineral water	Answers	Percentage
Yes	41	10.1%	Yes	374	92.3%
No	364	89.9%	No	31	7.7%
Total	405	100.0%	Total	405	100.0%

Over the past five years, over 69% of users have experienced water restrictions for more than 4 hours a day, although about 40% of people did not actually suffer real inconvenience, as 81% of the families surveyed have private reservoirs for their own needs. Nevertheless, about 1/3 of the people noted severe problems caused by water rationing.

The use of water in the tourist sector is obviously a potential source of conflict with the resident population.

The resident population's general opinion of tourists is basically positive (Table 5).

Table 5. Resident population's opinion of tourists [9]

Opinion	Answers	Percentage
Negative	56	13.8%
Neutral	142	35.1%
Positive	207	51.1%
Total	*405*	*100.0%*

Nevertheless, the co-existence of these two groups does encounter several problems. The worst impacts of tourism in daily life are perceived to be the production, management and collection of waste (62.0% of negative impressions), noise pollution (46.4% of negative impressions), urban crowding (41.5% of negative impressions), the crowding of beaches (39.8% of negative impressions) and traffic (36.8% of negative impressions).

As for water, the opinion of the resident people on the impact of tourists is especially important in the perspective of the participatory, shared and sustainable management of the resource. Conflicts between residents and tourists are not unlikely, as some 50% of the survey households feel that tourism has a negative impact on water supply, and 43% of them also think that tourism has a negative impact on wastewater management.

Within the survey group, the largest number of families (over 48%) consumes less than 50 m^3 of water per year, while 8.1% of them consume over 131 m^3 per year. This shows that a differentiated water pricing system could actually be established without heavily weighing on the low income and low water consumption groups (Table 6).

Table 6: Average yearly per capita consumption within the survey group [9]

Consumption (m^3)	Answers	Percentage
Up to 50 m^3	193	48.3%
51–90 m^3	137	34.3%
91–130 m^3	37	9.3%
Over 131 m^3	33	8.1%
Total	*400*	*100.0%*

In the perspective of an effective water policy based on an adequate price, however, it is important to detect the level of awareness of households regarding their current water bills. It is very surprising, in fact, to see that over 40% of the households have no idea of how much they pay for their own water. Only 14% of them say that they know their water bills. Among the families who were able to remember their yearly water expenses (56.3%), over 60% made mistakes of over € 100. This is a very worrying sign, as it shows that people are used to consuming water without even knowing the influence it has on their own budget. This also means that a policy of water savings based on water pricing will not easily work at first, as long as the families do not realize the costs of their lifestyle (Table 7).

Table 7: Level of awareness of the annual amount of water bills [9]

Level of knowledge	Answers	Percentage
Yes, precisely	58	14.3%
Yes, approximately	170	42.0%
Yes, but will not answer	14	3.5%
No	163	40.2%
Total	*405*	*100.0%*

The value of water depends on its price, but also on its quality and availability. If water quality is high and its availability is continuous and reliable, then its price can understandably increase.

As a pure and simple rise in the water price without a parallel improvement in the service is largely seen as unfair and unacceptable, the survey sought to detect the price level that households would be willing to pay in order to have a better service.

Two separate surveys have been performed. The first scenario proposed better availability, the second better quality.

In the first scenario, the basic hypothesis was a higher number of tourists in the summer months, leading to the inevitability of distributing water for only 6 hours a day (6 am to noon), as actually happened in the summer 2003. In order to avoid such restrictions, the public authorities would propose a programme of investments resulting in higher water prices.

As a result, 67.4% of the users declared no desire to pay more, while 24.4% of them declared an ability to pay up to € 20 more per year in order to avoid the restrictions.

Among the vast majority that did not accept the price rise, only 4% of them declared that they would reduce the amount of water they consumed. The rest altogether refused the idea of paying more, with over 28% openly blaming the tourist sector for the problem (Tables 8 and 9).

Table 8: First scenario. Acceptable increase in water prices for improved availability and reliability of service [9]

Accepted increase	Answers	Percentage
No increase	273	67.4%
Up to € 20	103	25.4%
€ 20 - 30	24	5.9%
Over € 30	5	1.2%
Total	*405*	*100.0%*

Table 9: First scenario. Reasons for not accepting any increase [9]

Reasons	Answers	Percentage
1. «I prefer to reduce the amount of water consumption.»	11	4.1%
2. «I can not afford to pay more.»	70	25.9%
3. «I do not think the service would actually improve.»	6	2.2%
4. «I do not think the infrastructures would actually be built.»	3	1.1%
5. «I do not want to pay for the tourists.»	55	20.4%
6. «I think hotels should pay more.»	15	5.6%
7. «I think the public authorities care more about the tourists than about the citizens.»	6	2.6%
8. «The bills are already too expensive.»	57	21.1%
9. Other answers.	46	17.0%
Total	*269*	*100.0%*

The second scenario did not involve a water availability crisis and prospected important investments in order to improve water quality. The response from the households was better than in the first scenario, with 42.7% refusing the price rise, but 44% declaring themselves willing to pay up to € 20 per year, and 11.9% of them up to € 30.

Among the negative answers, 16% of the households declared that they would still prefer to buy mineral water, while 8% did not believe that tap water quality could ever reach an acceptable level, and 27% of them simply declared that water is already too expensive (Tables 10 and 11).

Table 10: Second scenario. Acceptable increase in water prices in exchange for better quality [9]

Accepted increase	Answers	Percentage
No increase	173	42.7%
Up to € 20	178	44.0%
€ 20 - 30	48	11.9%
Over € 30	6	1.4%
Total	*405*	*100.0%*

Table 11: Second scenario. Reasons for not accepting any increase [9]

Reasons	Answers	Percentage
1. «I would still prefer to buy mineral water.»	27	15.8%
2. «I can not afford to pay more.»	46	27.1%
3. «I do not think the quality would actually improve.»	14	8.2%
4. «I do not think the infrastructures would actually be built.»	4	2.4%
5. «I am satisfied with the current quality of tap water.»	10	6.5%
6. «The bills are already too expensive.»	44	25.9%
7. Other answers.	24	14.1%
Total	*169*	*100.0%*

Overall, starting from the present water price of around € 1.60/m^3 (including all costs and taxes), in the first scenario (improvement in water availability) the new acceptable value would be € 1.69/m^3.

In the second scenario, instead, (improvement in water quality) people seem more willing to pay a higher price, which could be set at € 1.79/m^3. Overall, people in Alghero are willing to pay relatively high prices for their water, since the average price fixed by the Regional Government for potable water in Sardinia (December 2005) is € 1.14/m^3 (Table 12).

The risk of increasingly serious water crises has led the Regional Government to establish an ambitious plan aiming at gradually increasing the price of potable water to € 1.38/m^3 by 2015 and to € 1.51/m^3 by 2030. That would be an average, however, with considerable discounts for low-income and low-consumption classes. The tourist sector, with its intensive consumption, would consequently pay a much higher price.

Table 12: Price for drinkable water in Alghero [9]

Current average price	€ 1.60/m^3
Acceptable price with better availability	€ 1.69/m^3
Acceptable price with higher quality	€ 1.70/m^3
Average price fixed by the Regional Government of Sardinia - December 2005	€ 1.14/m^3

This study shows that a public programme aiming at supplying water of higher quality is actually able to influence the population's opinion on water resources, ultimately leading to a greater awareness of its financial, environmental and resource costs.

Whether or not higher prices, other than covering service expenses to a higher level, would also actually influence the consumption of water and thus reduce the pressure on this resource, remains to be determined.

Conclusions

A key constraint in the development of tourism throughout the Mediterranean area is the availability of water. Conflicts with other water users can arise, especially when tourism is highly seasonal, as in the case of Alghero. It has been demonstrated that efficient water management is more and more desirable, if the avoidance of conflicts and the reduction of unsustainable water uses must be achieved. In particular, a water policy based on higher prices in return for higher water quality seems to be a first step towards a greater awareness of the scarcity of this resource, and is supposed to provide a reduction in water consumption, thereby tackling the problem at its origin. Further research must be performed in this direction.

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Man, environment and risk

PhD works on geography of risk

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Abstract

Risk is a complex phenomenon, involving both physical and human factors, at different spatial scales. Risk is linked to specific territorial features, referring to territory as the result of the inter-actions between man and the physical environment; risk analysis requires a multi-disciplinary approach; geography provides useful concepts and methods for risk studies, especially concerning the analysis of territorial and spatial dimension of risk.

In this paper, we present some PhD works focused on risk analysis, performed by students of «Man and Environment», at the Department of Geography of the University of Padua (Italy). Since 2001, four PhD students have been working on topics linked to risk: landslides and risk perception; risk perception and repertory grids; wetlands and risk; hydraulic risk in reclaimed areas. The studies have been carried out in different risky territorial contexts. Risk processes have been analysed with different scientific approaches, based on human geography, geomorphology, natural sciences, and psychology, according to different students' specialization; all works consider territory and environment as key elements for risk analysis.

Keywords: Risk, geography of risk, risk perception, landslides, Tessina landslide, Lamosano landslide, Po Delta, acqua alta, repertory grids, hydraulic risk.

Introduction

Risk is a complex phenomenon involving both natural and anthropical factors; the relationships between physical and human factors have to be considered in risk analysis. There is no risk without man: e.g., a catastrophic event in a uninhabited area (having no impact on neighbouring inhabited places) will not be considered as a source of risk.

Risk studies focus on natural hazard, vulnerability and damage, considering their spatial and temporal patterns. Vulnerability has been defined as «the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard» [1]. The risk (R) faced by people is usually defined as a combination of vulnerability (V) and hazard (H):

R = H * V.

We can define territory as the result of the inter-actions of human societies with the physical environment; so we can say that risk is inscribed in territory, it is linked to a specific physical and human environment. It is part of of the features of the territory, and at the same time it influences the evolution of territory. A geographical approach is suitable for risk analysis, allowing a multi-scalar, systemic approach. Geography provides a complex of skills, concepts and terminology for the analysis of territorial and spatial dimensions of risk: e.g., the application to risk studies of concepts such as connectivity or complexity.

In this paper we present some PhD works focused on risk analysis, performed by students of «Man and Environment», at the Department of Geography of the University of Padua (Italy). Since 2001, four students have been working on subjects linked to risk (some works are still in progress); their main topics are:

- landslides and risk perception (case study: Tessina and Lamosano landslides, Italy), by Laura Giacomini;
- wetlands and risk (the Po delta, Italy), by Sara Ariano;
- «high water» and risk perception, repertory grids (Venice lagoon), by Luca Pezzullo;
- hydraulic risk in reclaimed areas, by Elisa Vanzo.

The studies have been carried out in different risky territorial contexts. Risk processes have been analysed with different scientific approaches, based on human geography, geomorphology, natural sciences, and psychology, according to different students' specialization; all works consider territory and environment as a key element of risk analysis. Sharing this interest in the geography of risk, students found it useful and fruitful to have a constant exchange in their research, sharing competences, reflections, bibliography.

Landslides and risk perception

Alpago, the part of the Bellunese Prealps that is situated on the northwest of the Cansiglio plateau, in the northeast of Italy, has been the subject of much geological and geomorphological research, due to a situation of slope instability that results in large active landslides, and because it is an area at high seismic risk. Among all human valley settlements, Chies d'Alpago has not only suffered damages from violent earthquakes throughout the centuries, but also presents morphological evidence of past landslides and situations of failure, which are still in progress. This study focuses attention on two large active landslides, those of Tessina and Lamosano, which involve the villages of Funès and Lamosano, part of the district of Chies d'Alpago. We used two different research approaches: a geomorphological approach and the analysis of risk perception.

The geomorphological study has been developed using GIS - software Idrisi 32; we modeled and classified both landslides. The analysis of risk perception has been undertaken through the analysis of several studies on the subject and a survey; for data analysis, SPSS (Statistical Package for Social Sciences) software was used.

The Tessina landslide, which takes its name from the stream along which the main body of the

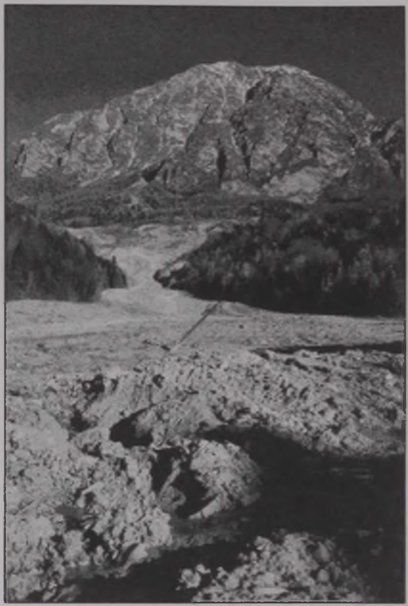

Figure 1: Tessina landslide and M. Teverone. The picture shows a part of the niche and the higher zone of accumulation of displaced material in November 2004.

Figure 2: Lamosano village

Figure 3: Lamosano, damages caused by local lowering movements in a restaurant parking. The restaurant is closed but the owners are still living there, even if the building shows serious damage.

landslide extends, is the partial remobilisation of a paleo-landslide (Fig. 1). It is a slow rotational slide, which evolves downvalley as a debris flow and a mudflow, due to the presence of superficial and subterranean water which makes the moving mass semi-fluid [7].

The Lamosano landslide is also a remobilization of a paleolandslide body (Fig. 2). The type of movement here is a slow translational slide of the ridge on which the village is situated, accompanied by a series of more superficial sliding movements, the most important of which are along the crown of the detachment niche. Phenomena of a dilative type are also to be found in some areas of the village (Fig. 3). Overall it is a translational movement of all mass involved, from east towards west, of a series of local lowering movements, still from east towards west near the crown of the landslide, and marginal failure throughout the flanks of the mass movement, in perpendicular direction to the landslide body pattern. The causes can be attributed to oscillation of the water table and to presence of preferential subterranean water paths [9].

These two landslides are at different evolutionary stages, with dynamics that have some aspects in common, but which create two distinct situations of risk in the two villages. Funès is only affected by the Tessina landslide, though it is very close by, whereas Lamosano is affected by the landslide of the same name, due to its position on a ridge in slow movement, and also by the Tessina landslide, whose foot, along the bed of the Tessina stream, has at this point reached the nearest houses. As a result the risk situation is different in the two communities.

The aim of this study is to discover, by means of analysis of the perception of risk, whether there is a different evaluation of the danger by the inhabitants of the two communities; if and how they react in the case of a landslide alarm; whether they adopt precautionary measures to prevent or at least mitigate situations of risk; whether the local authorities have prepared preventative actions and evacuation plans in order to guarantee the inhabitants' safety.

Both underestimating and overestimating could be dangerous. If the Government and the local authorities in charge of protecting the environment and the safety of the people living in the threatened areas underestimate a potential risk, they will not take the proper precautions to protect both the territory and the people. Overestimating a risk may result in a waste of time and resources by intervening in cases of environmental risks that may actually be not so imminent or even not so likely to happen. This situation could remove attention from areas where such a threat for the people and the territory is actually present. Underestimating a risk and the consequent lack of precautionary actions toward environmental threats are common human behaviours. However these behaviours do not include all human beings and all types of risks.

Studies from different areas of the world subjected to natural hazards, such as floods, earthquakes, etc., show that a high percentage of the people living in these areas refuse to accept the likelihood that the catastrophic event may happen again within a few years. Furthermore some people think that the event won't happen again for the rest of their life. In this way they will not take precautionary actions to prevent damages [6].

The survey was mailed together with an accompanying letter bearing the heading of the Department of Geography of Padua explaining the purpose of the survey, which was also encouraged by the local authorities. The letter also stated that the survey was addressed to all family members above the age of 18 years and that help in answering it would be available if needed. We mailed 243 questionnaires to Lamosano and 81 to Funès, to a total of 166 families. We were able to get back 161 questionnaires in Lamosano and 71 in Funès, to give a total of 232 out of the 324 we distributed.

The population's response to this research was excellent, permitting us to carry out the analysis of risk perception on a large sample, and therefore to obtain reliable results. In contrast to what is found in most of the literature on the subject, the communities of Funès and Lamosano have an accurate perception of the risk of landslides and have developed a correct relationship with the objective risk.

Therefore, there is neither underestimation nor overestimation of risk. Even though there is a lack of widespread information, especially relating to the evacuation plan and the landslide alarm system, people of Funès and Lamosano living in areas where the hydro-geological risk is high are fully aware of the risky situation in which they live, and if the occasion arose would react accordingly. In the case of an alarm, people's reactions would be quite varied: mainly regarding which direction to leave or which means of transportation to use. There is an evident lack of coordination, which would be improved only if directed by a specific organization, which would have to follow the evacuation plan that we debated in this study.

Wetlands and risk: the Po delta (Italy)

This thesis focuses on functions and values of wetlands in risk management. The research is applied to the case of wetlands in the Po delta (Italy). We investigate the history, perception, and functions of wetlands in these areas in order to understand whether the man/environment relationship, especially concerning uses of wetlands, has had consequences on increasing vulnerability.

According to the official definition in the Ramsar convention (1971), «Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres» (Article 1.1). In addition, Ramsar sites «may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands» (Article 2.1). Even if this definition may appear quite precise, wetlands are sometimes difficult to individualize; they are changing environments, interfaces between water and dry land.

Wetlands are characterised by high biodiversity and ecological functions. Nevertheless, they are also fragile, undervalued and despised; their number has dramatically reduced during the XXth century. The functions of wetlands have traditionally been underestimated: they were perceived as wastelands. For a long time wetlands have been considered as unhealthy and unproductive spaces; in Italy, in particular, marshlands and ponds were associated with malaria. Draining (bonifica) was the only solution to make them useful to human society.

We can speak about a recent «passion» for wetlands: the opinion about wetlands has changed amongst scientists and society in general. Wetlands are especially appreciated for high biodiversity value and natural heritage; their conservation has become a primary issue for biodiversity and sustainable development. But other values and functions of wetlands are still neglected, in particular concerning risk prevention.

Wetlands can be considered as a key-element for risk management. They contribute to flooding risk mitigation, acting as retention basins. In periods of droughts, they help to maintain surface water flow and assure water supply. These functions can be referred to as «hydrological functions». Wetlands can also be exploited to improve water quality, through the retention and transformation of some polluting substances and nutrients (from the use of chemical fertilizer); such a filtration process, named phyto-depuration, relies especially on abundant wetland vegetation [5].

Case study: the Po delta

The Po delta (in Veneto region) is located in the north-east of Italy. In this area a Regional Park was created in 1997, on an area of 12592 ha. Our study aims at evaluating the integration of wetlands in risk management plans. We also want to compare people's perceptions of wetlands and risk with management plans; this work will be carried out also through a fieldwork study and interviews. Even though our work is still in progress, we can already find some results. The main environmental risks considered are flooding, drought and pollution:

• In the delta, ground level is generally under sea-level (on average: –2 / -3 m); in order to keep reclaimed lands dry, water-scooping machines have to be used continuously. Subsidence is

Figure 4: Po river embankment: normal flood level is higher than ground level. The village in the picture is next to the embankment, increasing vulnerability.

mainly due to the extraction of methane, practiced in this area until the Sixties. In this area, Po is a suspended river: normal flood level is higher than ground level, as can be observed comparing ground level and water level from the embankment (Fig. 4). This situation increases flooding risk; moreover, villages are often next to the embankment, increasing vulnerability.

- Pollution may be generated by agriculture (pesticides, fertilizers) and by industrial activities; a thermo-electric power plant, Polesine-Camerini, is located just next to the limits of the Park. Other projects for this territory are based on the promotion of energy and industrial activities: creating a new industrial zone, converting the power plant to coal, building a gas terminal and a regasification plant.
- Three severe droughts occurred in the last 4 years, in the summers of 2003, 2005, and 2006. Droughts are associated with salt water intrusion up to 20 km from the coast line, with evident effects in the delta: about 15.000 inhabitants did not have access to potable water. The droughts caused irreparable damage to agriculture, destroying rice cultures and damaging corn and horticulture.

According to our hypothesis, people's perception is characterised by undervaluation of these risks, excepted for droughts; droughts are well represented and perceived in public opinion, due to their frequency and visible effects. Wetlands functions for risk prevention are generally ignored, their integration in risk management is extremely marginal. Official management plans are essentially based on hydro-geological features, with simple calculations of flood level; but technical analysis of natural hazard cannot completely explain a complex risky territorial context: vulnerability is increased by human behaviour, linked to cultural, social and historical factors.

Risk perception: repertory grids

In the Risk perception field, many studies focus on the links between attitudes, cognitions and perceptions of specific risk situations. Recent research in social and cognitive psychology shows that the «classical» view of risk perception could be somewhat flawed by the use of too strict methodological tools. To understand the implicit structure of meaning that people hold about environmental risks (e.g., the semantic structure on which psychological attitudes are based), we need to use assessment tools more focused on mental model structures and «psychological constructs» (e.g., «units of meaning»), adapted from clinical assessment practice.

We are working on adapting «Repertory Grids» systems to geographical mental models studies. RepGrids are an interesting mix between qualitative and quantitative techniques, based on correlational psychometrical approaches. In a substantial different way from a questionnaire, in a RepGrid the subject himself chooses the scales, the concepts and the «structures of meaning» to be used. Applying these instruments to people living in disaster-prone areas gives powerful tools for analysing widely spread assumptions, cognitions and «folk-physics issues» related to environmental processes; exploring such a variety of raw data, Repgrid Analysis (based on Cluster Analysis and Correspondance Analysis) can discover hidden patterns in the conceptual structure held by people about different hazards.

We are testing these tools with people living in water-related disaster-prone areas in Northern Italy, in particular some Venice Lagoon towns. In these areas, people are interested by two types of water-related risks:

1) floods and flash floods caused by «Acqua Alta» («high water») processes;
2) water pollution and chemical contamination from Porto Marghera industrial site.

The first results show an interesting cognitive mental model for «High Water» processes, conceptualised by stakeholders as very «different» from normal flood events. Among other results, we obtained that:

- many experts, while having a good explicit theoretical competence on natural hazard processes, show mental models with implicit, persistently «wrong» hazards representations;
- a Hazard is cognitively perceived only as «natural» or «man-made», in an exclusive and dichotomized way; this could implicate a persistent difficulty for stakeholders to represent correctly the human role and responsibilities in natural processes and environmental hazards.

Hydraulic risk in reclaimed areas

The methodologies and analysis of the informative systems used to face the problem of hydraulic risk in reclaimed areas propose a form of more structural coordination between the basin planning and territorial planning. With this work we want to promote a map-making representing all the different kinds of hydraulic dangers within the considered region, highlighting the interested areas and, where possible, the cause of the danger. The final task is to monitor the risky areas, using the different levels of human activities and of the environment property. This is done by overlaying the map of alluvial phenomenon and the settlements.

The identification of the dangerous areas is necessary to predispose the most urgent precautionary measures, through structural intervention related to the particular hydro-geologic conditions, aimed at achieving soil conservation and environment defence against the dangerous effects of the human activities.

This work does not aim to be a strict mathematical study about the different events, but it aims to analyse all the possible causes of danger for the territory and interested areas. The exhaustive identification of all the possible dangerous situations due to the hydro-geological conditions of the area can be carried out using complex geographical methodologies that are able to compute the likelihood that one of these events can happen in areas never touched by these phenomena in known history.

Conclusions

Which synergies are possible between human geography, geomorphology, natural sciences and psychology? In risk analysis, a transversal study associating geomorphology, human geography and psychology is useful to obtain an adequate comprehension of complex processes.

Through the analysis of risk perception, we can understand the different evaluation of danger by people living in natural hazard prone areas, whether they adopt precautionary measures to prevent or at least mitigate situations of risk. People's responses, together with consideration of territorial features enables an evacuation plan to be drawn up..

People's behaviour depends on risk perception of threat; perception, which is strongly influenced in each human society by its history, its own peculiarities, and especially by the specific features of the man/environment relationship. So the same risk can lead to very different results in the territorialisation processes accomplished by different human societies. A geomorphological study completes the territory analysis, allowing a morphological assessment and description of the natural hazard prone-area.

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Methodologies in a geomorphological approach: examples from the Po Plain of Venice

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Abstract

The principal aim of this paper is to indicate the more appropriate methodologies for geomorphological research in a «low plain» context. The methodologies are applied in two study cases: one is centered on the middle of the Bacchiglione River and the other on the Montegrotto Thermae Neronian site; in both there are strong interrelations between geomorphic processes and ancient cycles of human occupation. Thus in the areas of interest, stratigraphic records of buried soils are often associated with archaeological remains.

Keywords: Microrelief; remote sensing; alluvial plain; fluvial geomorphology; geo-archeology, Po plain

Introduction

We use the term «low plain» to describe the distal part of the «megafans» which form the north-eastern Po Plain. The morphology of the low Venetian plain is a product of cyclical fluvial depositional processes (the main forms are: fluvial ridges, natural levees, crevasse splays, floodplains) and erosional ones (incised fluvial channels) [5].

The proximal parts of megafans are characterized by coarse fluvial material such as gravel and pebble in a sandy matrix. The distal parts are made up of fine deposits made of clay, silt and sand; and the slope is very gentle. This sharp difference in the granulometry of sediments caused by a reduced fluvial transport capacity allows one to distinguish the high plain (characterized by greater permeability and thus by a reduced superficial hydrography) from the low plain, where there are less permeable conditions. Here the hydrography has a more constant regimen, also due to the presence of springs at the border between the high and low plain (the so-called «linea delle risorgive», which borders the whole alpine side of the Po Plain).

The two study areas are located on the western part of the low plain produced by the Brenta-Bacchiglione fluvial system.

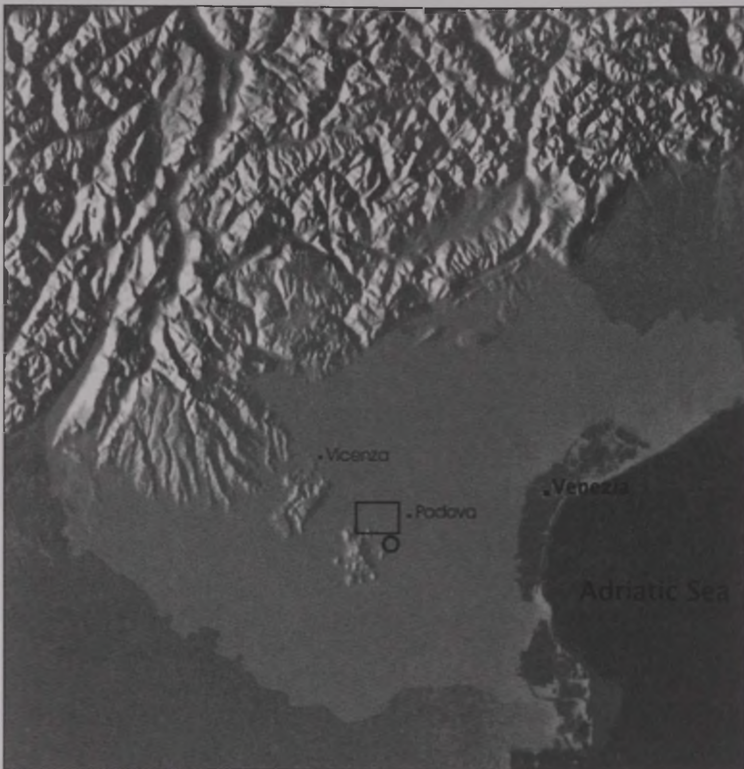

Figure 1: Regional view; the rectangle is the Montegalda-Selvazzano area and the circle is the Montegrotto Neronian site.

Areas of interest

The Thermae Neronian site in Montegrotto

Archaeological excavations have partially revealed a wide monumental complex articulated in a series of rooms characterized by very elegant decorations such as opus sectile-made floors and black and white mosaics. Some of these are in very good condition. The typology of the floors and the quality of the materials collected seem to indicate that the complex was built between the end of the 1st century BC and the beginning of the 1st century AD. Aerial photographs show that the buildings cover a large area, but the function of the complex is still not clear, because the current investigation is limited to a smaller area. From previous archaeological studies it seems that these buildings formed an ancient villa owned by wealthy private householders. As monumental pools fed by thermal water lie only a few hundred meters away from the villa, the likely connections between them and the villa should be verified.

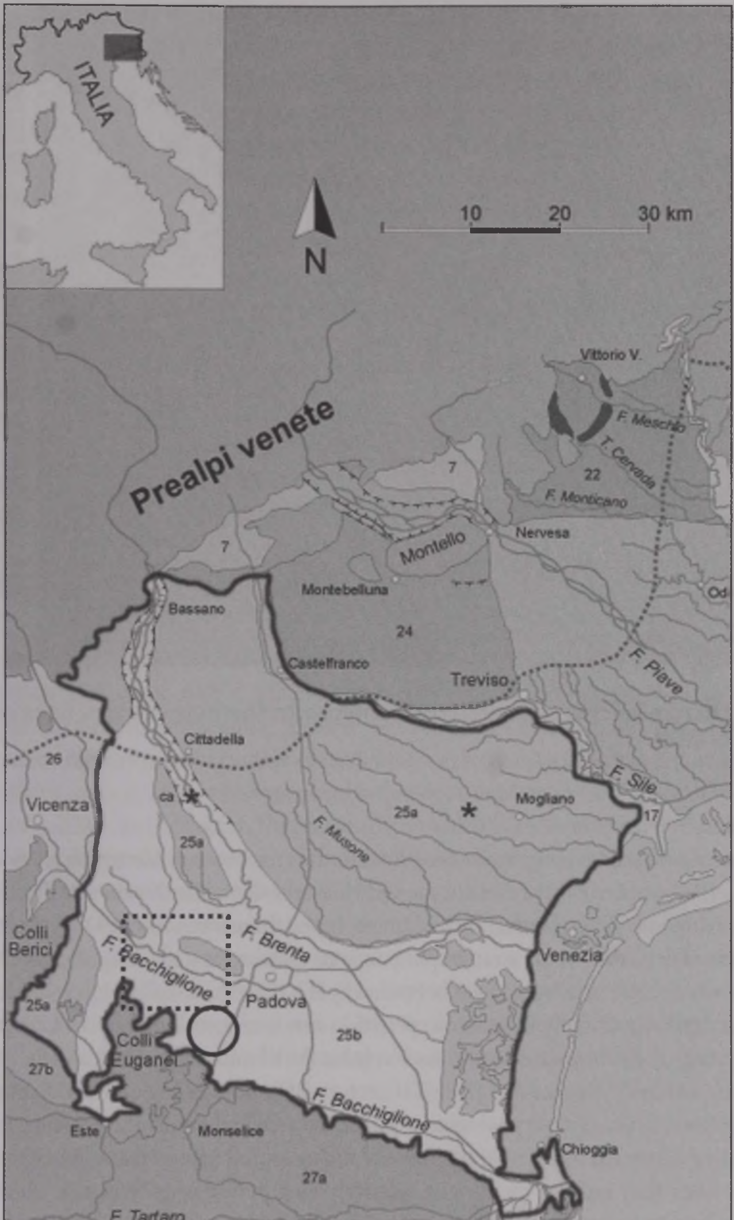

Figure 2: Brenta Megafan: the dark gray color denotes late Pleistocene deposits and the light color represents Holocene deposits. Fontana et al. 2004 modified.

Figure 3: Microrelief chart centered on Montegrotto Thermae; contour lines with equidistance of 0.5m.

Montegalda-Selvazzano

The geomorphological investigations carried out in the area between Montegalda (Vicenza) and Selvazzano (Padova) involve the Pleistocene and Holocene fluvial landforms and the fluvial ridge that the Bacchiglione River is currently building between the artificial dikes. Deposits and related soils have been described in the stratigraphic sections that are located on the concave side of the meanders, which have been considerably eroded by the river's unusually high water level in the summer of 2003. Geomorphological interpretation meets archaeology here too, given that the first archaeological findings date back to the Neolithic (V-VI millennium BC), and that settlement cycles continued in the Bronze Age (XIII-XII century BC), Roman Age and Middle Ages [1]. As a result, we present the geomorphological chart of the area and report the presence of a buried soil extending a few km and containing several archeological inserts from the Higher Middle Ages. This latter may indicate an ancient, relatively long period of geomorphic stability; these conditions seem to be interrupted after the Higher Middle Ages.

Methodologies

Microrelief interpolation and analysis

Microrelief analysis is essential for geomorphological study in a plain land, because the relief of the examined area is not easy to view from topographical maps, and is often imperceptible from a field survey. In fact, the slope is very poor in low plains (1–2‰) [3]. Thus we need to build a detailed altimetric chart of the investigated area that is characterized by contour lines with a necessary equidistance, which can vary from 0.5 to 1 m. The altimetric chart (Fig. 3) is based on the point contained in the C.T.R. (Carta Tecnica Regionale del Veneto) map, which has a scale of 1:10 000.

For the construction of the contour lines, a manual interpolation of the altitude is adopted. This method makes it possible to factor out points that are related to human manufacture (bridges, streets, buildings etc.), which can mask the natural morphologies. After interpolation, we can digitize the contour lines in order to elaborate them, by building a DTM with the aid of GIS software [4].

Microrelief analysis is fundamental for the characterization of fluvial ridges, depressed areas and escarpments; often these morphologies can be detected only using this method on the low gradient that distinguishes them from the rest of the plain.

Satellite remote sensing

In comparison with aerial photos, which contain only geometrical information, satellite image analysis has the advantage of adding spectral information to the examined area. Spectral data are acquired by sensors that are capable of recording the electromagnetic waves that are reflected or emitted by a surface. These sensors could be «passive», such as photographic equipment and scanners, or «active», such as radar. The framework in which the sensors are placed is represented by the shooting platform. A set composed of both sensor and platform forms the remote sensing system, which could be terrestrial, aerial or spatial.

In the analysis process, objects that due to their homogeneous physical properties have similar morphological characteristics (shading, structure, texture and morphology) are defined as «objects». Objects can be divided into two groups: those that lie on terrain that can therefore be directly interpreted, and those that cannot be directly perceived, including buried structures, both naturals (faults, mineralized bodies) and human (nets of irrigation channels, ancient tracks and boundaries, archaeological remains). The buried structures require morphological and morphometric interpretation through the analysis of the surface indicators (soil humidity, vegetation, microsurvey), which often represent the «epidermic reflection» of deeper structures.

The study of the forms recognition and the spectral signal of the «objects» is performed using both analogue (photography, optics, electronics) and numerical (digitalization, statistics, image processing) methods. The analogue method considers the spatial analysis of forms and structures, while the numerical method mainly focuses on the interest in spectral responses

Figure 4: A paleochannel near Selvazzano, clearly evident in an aerial photo from 1982

analysis, in other words it considers the energetic behavior of any surface. The last stage of the analysis process is image interpretation, which looks at the images as a result of the interaction between the electromagnetic energy emitted from a generic surface and a photosensitive recording system.

Satellite images are useful for the understanding of superficial geology and the relations between morphologies; these often have a medium-large scale view, but in the last years there has been an increase in geometric accuracy.

Aerial photo interpretations

Interpreting aerial photographs chosen with the right temporal characteristics brings a detailed geometric resolution and a general synthetic view that is important for the correlation of distant morphologies.

In photos, contrasts in tone arise from different humidity conditions that are caused by the different texture of deposits and are reflected by the vegetation cover. This allows one to recognise and map traces of natural forms (e.g. paleochannels, fluvial divagations) and superimposed human interactions (e.g. ancient roads, agricultural boundaries); the latter are particularly difficult to see with any other method.

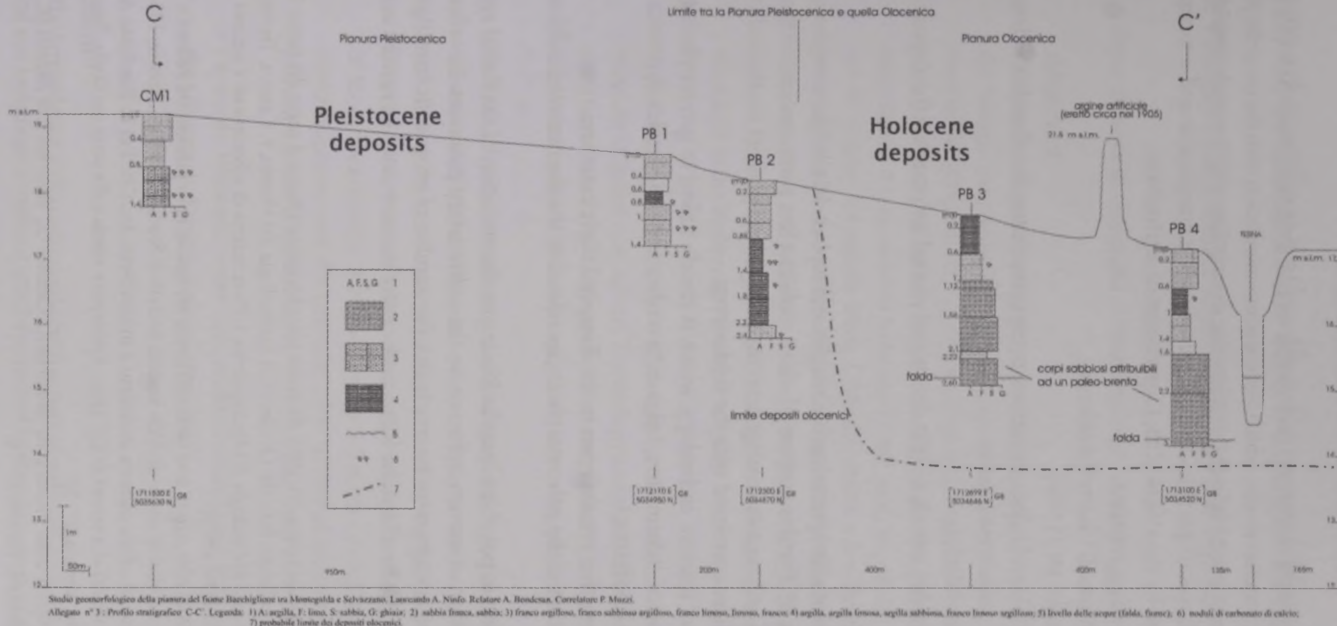

Figure 5: Example of a stratigraphic correlation that shows a part of the ancient Pleistocene plain probably eroded and filled by the Holocene Brenta activities, Veggiano.

Field survey

After looking at an exposed section or a drilled core, we take the geographic position by the mean of either GPS or metric measurements, which involve some calculation with the co-ordinates of a very large-scale map. Then we can begin the stratigraphic description, which mainly consists of [2]:

• Texture: size classes of particles using a granulometry comparator and a textural triangle based upon that used by the USDA (U.S. Department of Agriculture).

• Structure: type of aggregation

• Colour: using Munsell Charts for colours.

• Carbonate content: HCl (10%).

• Included materials and colour variations: using comparators for abundance density estimation, and charts for percent estimation.

• Stratigraphic boundaries.

For every stratigraphic record, a log is drawn and plotted for correlate the deposits.

Conclusion

With the application of appropriate methodologies and tools, a detailed geomorphologic cartography can be produced. For this purpose, the best tools in a low plain context are the analysis of detailed microrelief and remote sensing data (including aerial photos) for the individuation of landforms that are later correlated with the field survey.

In the two areas of interest, archeology, which is closely linked to geomorphology, bringing important chronological information, helps us to understand the complex dynamics that create fluvial deposits and landforms.

The main questions that remain open in the discussed study cases are:

1) the determination of the paleomorphologies related to the documented cultural layer and horizons;

2) the identification of possible allocyclic forcing on the evolution of the fluvial system;

3) the determination of human influence on the sedimentary processes. In order to answer these questions, field surveys must be continued, the number of geognostic investigations must be increased and, in the Bacchiglione River, underwater research must be carried out.

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Uses of wetlands in the Senegal river delta

The villages in the buffer zone of the part of Djoudj (Senegal)

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Abstract
This paper analyses the evolution of wetland uses from tradition to «modernity» in the Senegal river delta. The investigation was focused on the villages in the buffer zone of the National Park of Djoudj (Parc National des Oiseaux du Djoudj). The park was created in 1971 in the middle delta of the Senegal river, on the border of Mauritania; it is considered to be one of the most important wetland sites in the world, notably for aquatic birds. Until the sixties, a few thousand people used to live inside the present protected area; traditional land uses were based on abundant water resources and wetlands. With the creation of the park, people where forced to leave their lands; access to protected areas was forbidden, their villages were displaced to the buffer zone around the park.

In the same area, hydraulic works were carried out since the sixties in order to promote irrigated rice culture. The ecology and the hydrology of the Senegal river delta have been deeply changed by the construction of embankments and dams. In water management, priority is given to rice, to the prejudice of other land uses.

Traditional uses are generally undervalued, although they are important for the subsistence and the development of several villages. Wetland uses, between tradition and modernity, can be considered as a key element for analysing the interaction between local/external actors, power relations (weak/strong actors), and features of local development. Wetlands are the element of continuity between the old territorialisation and the new one. New territorial identity, new social, cultural and economical values are being built, starting from wetlands.

Keywords: Wetlands, water uses, traditional land uses, buffer zone, Parc National des Oiseaux du Djoudj, Senegal river delta

Introduction
The delta of the Senegal river is characterised by high variety of wetlands, both natural and artificial [7]. The ecological and hydrological systems are characterised by the alternation of a rainy season (about

July-September) and a dry season. In the past (before the construction of dams and embankments), abundant rain caused augmentation of water flow and caused the river to flood; during dry season there was a strong level of salt water intrusion. For traditional societies in this area, wetlands and seasonally flooded areas used to be the core of the economic system, providing water for agriculture, cattle-breeding and domestic uses (drinking, cooking, etc.). Other activities were linked to water and wetland resources: fishing, collecting aquatic plants for alimentary use (water lily) and for the craft industry. Wetlands were integrated in the economic, social, and cultural system: a number of legends, rites and ceremonies are evidence of the central role of wetlands (an inventory of cultural values linked to wetlands in the delta was elaborated by Kane, Bousso and Dia [6].

The territorial context has been drastically transformed by human action during the last 40 years, through the construction of embankments and dams. Hydraulic works have allowed artificial regulation of the water level. The administrators aimed to create adequate conditions for developing irrigated agriculture, especially rice, the production of which was considered to be a basic condition for achieving alimentary self-sufficiency. The first phase of hydraulic work was the construction of the embankment on the left bank of the Senegal river, over 80km of length in the delta, in 1964. But the most important works were the Manantali dam (1988) on the Senegal river in Mali, and the Diama salt-intrusion dam (1986), in the delta. Nowadays the variation of water level is artificially managed: flood and low water in the Senegal river are regulated by the three neighbouring countries, Mauritania, Senegal and Mali, associated in the OMVS (Organisation pour la Mise en Valeur du Fleuve Senegal) [3].

Water management gives priority to the needs of irrigated agriculture, to the prejudice of previous traditional land uses such as agriculture in flooded ground depressions. Nevertheless, traditional uses are still practiced, even if their importance is generally underestimated. In order to investigate wetland uses, we focused on a case study: the villages in the buffer zone of the National Park of Djoudj, in the middle delta. These villages were chosen because of the leading role that wetland uses still have in their economic and social life. The study also leads to some reflections on local development and nature conservation in developing countries.

Fieldwork study in the buffer zone: methodological and conceptual instruments

The investigation on the Djoudj was carried out during a one month fieldwork study in the Senegal delta, from January to February 2006. Data were mainly collected from documents and a survey in the town of Saint-Louis. Fieldwork was conducted in the villages in the buffer zone of Djoudj, by interviewing inhabitants and administrators.

This analysis is part of a study on the Senegal River Valley by seven researchers comprising teachers and PhD students from the Department of Geography, University of Padova (Italy), in 2005–2006. The conceptual approach is based on the analysis of hydraulic territorialisation [5]. We consider territory to be the result of the inter-action between human and physical factors; the process of constructing territory is named territorialisation. On each territory, there can be a succession of several phases of territorialisation an re-territorialisation; so the geographer may

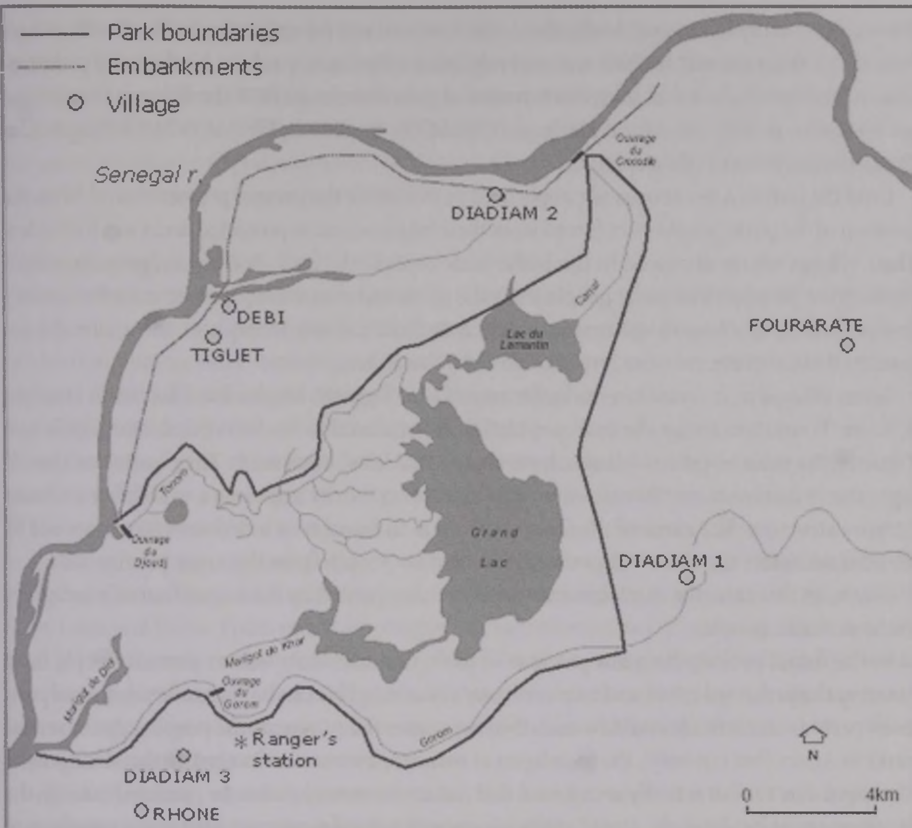

Figure 1: The National Park of Djoudj (PNOD)

find in the present territory, signs of the superimposition of several territorialisations [7].

With the hydraulic works carried out in the Senegal river delta, a new phase of territorialisation began: a new territory was built. The present delta is the result of the priority given to the needs of irrigated agriculture; it is unfavourable to traditional land uses linked to the previous territory.

Wetland uses, between tradition and modernity, can be used as a key element to analyse interactions between local/external actors, power relations (weak/strong actors), and features of local development.

The national park of Djoudj: nature conservation and water societies

The National Park of Djoudj – in French Parc National des Oiseaux du Djoudj (PNOD) was created in 1971. It is located in the delta of the Senegal River, on the border of Mauritania; the surface area of the park is about 16 000ha. It is considered to be one of most important wetland sites in the world, notably for aquatic birds: this is the first wetland for migrating birds after they have passed the Sahara desert in their seasonal migrations. For its key role in biodiversity preservation, it has been included in several international conventions: in 1977 the Ramsar Convention on Wetlands, in 1981 the World Heritage (UNESCO), in 2005 in UNESCO MAB Program, as Cross-border Reserve of Biosphere.

Until the sixties, a few thousand people used to live inside the present protected area. With the creation of the park, people were forced from their lands; access to protected areas was forbidden. Their villages where displaced to the buffer zone around the park. Some «compensation measures» were proposed: to make people leave the protected area, authorities promised monetary compensation, new houses and new jobs in irrigated rice culture. In any case, those who did not leave of their own accord were forced to do so by the police.

Seven villages were created in the buffer zone: Debi, Tiguette, Diadiam 1, Diadiam 2, Diadiam 3, Rone, Fourarate. Today the total population is estimated to be 3800 inhabitants; Debi and Tiguette, the most populous villages, have about 1000 inhabitants each. The creation of the villages shows demonstrates the existence of an external authority imposing a well defined administrative structure. The name of the three Diadiam is an example of a denomination imposed by an external actor: the three villages were founded by people from the same pristine village of Diadiam; in this case, the displacement was also accompanied by the imposition of a sedentary life to nomadic people.

In the initial period, the main purpose of park administrators was to prevent people from entering the protected areas, and to punish any violations; this can be referred to as the «repression» period. This attitude could be described as «conservation against the people». As for several parks in Africa (but not only), the paradigms of nature conservation changed: in the Management Plan signed in 1987, it is firstly recognised that nature conservation is to be obtained through the involvement of local people, aimed at the wise use of natural resources. That is the paradigm of conservation «for the people»[2].

Protecting nature… but which nature?

The choice of creating an integral natural reserve, displacing the villages and excluding any human presence inside the protected area, is usually intended to preserve a situation of primitive, virgin nature. When the park was created in 1971, the Senegal delta had already been drastically transformed by human action. The process of artificialization had already started with the embankment on the left bank of the Senegal river, and the first irrigated rice schemes were in place. Manantali and Diama dams have definitively transformed the hydrological system. So we can say that the «Nature» protected by the park is actually the result of territorial transformations induced by human actions.

Dams and embankments have had dramatic consequences on the ecosystem. Especially Diama dam, preventing salt water intrusion (which could compromise irrigation), has induced an alteration of water chemical parameters. The lower degree of salinity caused the disappearance of several vegetal species, whose ecology was based on the alternation between freshwater and saltwater: e.g.

Acacia nilotica, whose wood and fruits were used for medical purposes and to extract a dye, and nymphea lotus, whose seeds were collected for alimentary use. On the other hand, desalinisation has led to the proliferation of aquatic infesting weeds such as typha australis, pistia stratoites and salvinia molesta. Water quality has also been compromised by chemical pollutions, mainly due to the use of fertilizers and pesticides; also the sugar-refinery CSS (Compagnie Sucrière du Sénégal) seems to be responsible for water pollution.

Before the park: traditional wetland uses

Before the creation of the park, main economic activities used to take place around wetlands and in sectors exposed to seasonal inundation. Each village was specialised in one type of activity and production: fishing, cattle-breeding, craft industry. The main economic activity for each village depends on the ethnical origin; three ethnic groups are present in this area: Wolof, Maures and Peuls. Agriculture is typical of Wolof villages, fishing of Maures and cattle-breeding of Peuls. The local economy of each community was complementary to those of neighbouring villages: this situation resulted in a system of exchanges and commerce between the villages.

The main traditional land uses based on water and wetlands were as follows:

- Fishing, mainly carp and perch. Abundant ichthyic resources exceeded the needs of the villages; fish was dried and commercialized, with the intermediation of traders, in the towns of Saint-Louis and Dakar. Fishermen used pirogues to reach river sectors abundant in fish. Nowadays, fishing is still the main activity for some villages, but the situation is getting critical: ichthyic stocks have been reduced by pollution and by the construction of dams, which stop fish displacements, interrupting ecological connectivity. Moreover, proliferation of infesting weeds on water surfaces impedes the movements of fishermens' pirogues.
- Cattle-breeding, especially goats and zebus. This activity, based on seasonal transhumance, was extremely important in the delta; numerous wetlands in the Djoudj were used to water the animals. Today it is forbidden to take animals into the protected area. Moreover, cattle-breeding is suffering from the general evolution of territorial organization in the delta: transhumance paths are interrupted by fenced cultivated areas.
- Agriculture was traditionally carried out during the rainy season (pluvial culture) or in the depressions exposed to seasonal flood (décrue culture). Traditional agriculture was drastically limited by the expansion of irrigated agriculture. Nevertheless, the inhabitants of some villages, especially women, used to grow vegetables near small watercourses (marigots), where water was easy to reach. This activity is no longer practiced, since small water bodies are no longer accessible, due to the proliferation of infesting weeds.
- Craft industry, with the production of typical mats made of aquatic plants (*Typha australis, sporobolus*). The mats, especially those made with sporobolus, are considered of great value; making a mat is a long and skilled craft process, generally carried out by women. The commercialization of these products is quite difficult: craftworks are sold to tourists, especially in the souvenir shop at the entrance of the park.
- Collecting water lily (*Nymphea lotus*) seeds for alimentary use: the seeds were dried and

cooked like rice. Nowadays, water lily has almost disappeared due to the transformation of ecological conditions in the delta.

Besides productive uses of wetlands, we should also consider other uses such as transportation on the river. Wetlands also provided the mud for making bricks (banko) and water for domestic uses (drinking, cooking, etc.). Despite the abundance of water resources in this area, the access to drinkable water is today one of main problems for the inhabitants, with severe socio-sanitary consequences.

New uses of wetlands

The main economic activity today is irrigated agriculture: about 80% of the inhabitants of the buffer zone work in the nearby rice schemes of Débi-Kheun and Boundoum. Traditional uses are still practiced, in association with irrigated agriculture. The Wolof ethnical group, whose economy was traditionally based on agriculture, have more easily adapted to the new context dominated by irrigation; adaptation has been most difficult for the Maures and the Peuls, who used to be fishermen and livestock breeders respectively.

During the investigation, we asked administrators and people from the buffer zone if there is any place left for traditional uses of wetlands today. The answer was always: «No». In fact, traditional uses are generally undervalued and underestimated by administrators, although they are important to ensure the subsistence and the development of several villages. These uses are limited by several factors, such as:

- prohibition or bureaucratization of the access to natural resources inside the protected area (some permission can be accorded to the inhabitants by the guards, but this procedure is not common);
- proliferation of aquatic plants;
- pollution, compromising water quality;
- fragmentation: transhumance paths are interrupted;
- artificial management of floods and low waters.

Realising the consequences of the disappearance of traditional uses, some solutions were proposed by NGOs in association with local authorities; the results have often been inferior to the expectations. For example, in the village of Diadiam 3, an NGO started a project of irrigated horticulture, in order to replace traditional horticulture near watercourses; but the project failed a few years later, when irrigation pumps were stolen. This case is exemplary of a project that started well, but failed because it was not followed through for an adequate period. Other projects were conceived without considering the characteristics of the environment and of the social and technical background of local people: for example, an essay was carried out to replace traditional fishing by introducing pisciculture with floating cages.

In the new territorial context, the inhabitants had to «invent» new uses, new competences, new territorial knowledge. Some possibilities come from tourism in the park. People from the buffer zone have been involved in tourist reception: souvenir shop, hostel, restaurant, tourist guiding (Figure 2). These structures are managed by inhabitants associated in a GIE (Groupement d'Intérêt

Figure 2: New uses of wetlands: pond near the hostel Campement Villageois «Le Njagabaar»

Economique). The tourist shop «Boutikbi» is also a point of commercialization for craft works (mats, necklaces, tan leathers articles) produced in the villages. Some inhabitants are also involved in nature conservation and environmental education: in particular, the association of the eco-guards (in French: écogardes). The eco-guards are 35 volunteers (5 from each village), both men and women, of different ages and with different degrees of education; their task is to support the rangers in the park, being intermediaries between official authorities and the local population, and to promote a culture of nature conservation and wise use of natural resources. These activities have been initiated with the help of international cooperation. They are exemplary of the new paradigms described as «conservation for the people», characterised by the will to involve local societies in nature protection and in the wise use of natural resources. Nature conservation is in this way presented as an opportunity, rather than a restraint for local development.

Nevertheless, we observed that the inhabitants of the villages seem to be weak actors, faced by strong external actors. Concerning tourism, local people cannot always compete with external actors: tourists visiting the park come with guided tours, organized by agencies or individuals from Saint-Louis or Dakar, without any contact with the people of the buffer zone. Despite these difficulties, tourism is generally perceived by inhabitants as a concrete opportunity for local development.

Conclusions

The introduction of irrigated agriculture has led to a new territorialisation process in the Senegal river delta. The transition from the ancient territory of traditional societies to the new territory of irrigated rice is a complex process involving several actors at the local, regional, national and international level. The modern territorialisation is limiting traditional uses linked to the previous territory; nevertheless, traditional activities persist, and can be important to ensure subsistence and local development [7]. The case of the villages in the buffer zone of Djoudj is exemplary of this complex transition from pre-dams territory to the new territorialisation of irrigation and dams. In the buffer zone some traditional uses still persist, despite of the difficulties, people's displacement and prohibitions.

Displacing the villages produced severe consequences at the economic level, and in the social and cultural fields as well. The present villages show signs of a forced displacement and re-construction, as can be seen from the sometimes quite precarious juxtaposition of different structures of habitation. This new territory has suffered from the choices of external actors; the actual participation of local people in political decisions concerning their own territory is quite limited. Some structures were created in order to increase the participation of all stakeholders in land management: the inhabitants of the villages can participate in some «technical commissions» on cattle-breeding, natural resources, fishing, craftworks, health, etc. But these commissions seem to have a slight impact on the actual decision-making processes.

There is no easy solution to reach an efficient and harmless co-existence of traditional values and modernity in this field. The study and the fieldwork analysis led to some reflections and statements, as exposed in the previous paragraphs, but several questions still remain unanswered.

Some interesting possibilities for local development come from tourism; such activities are focused on the valorisation of local heritage and natural resources. Moreover, we observed the construction of a new territorial identity based on the awareness of a unique natural heritage; this new local identity is emphasized by people involved in tourist reception and guiding, but it seems to be shared as well by other inhabitants of the seven villages. In this way, new social and cultural values are associated with new economic uses. Wetlands can be considered as the element of continuity between the old territorialisation and the new one. New territorial identity, new social, cultural and economical values are being built, starting from wetlands.

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Soil and water conservation techniques in Burkina Faso

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Abstract

Desertification is known to be a complex phenomenon involving different disciplines such as soil science, meteorology, hydrology, range science, agronomy, veterinary medicine, as well as geography, political science, economics and anthropology. This document proposes a transversal approach because it defines natural resource degradation in many perspectives and it emphasizes several aspects to obtain an adequate comprehension of this environmental problem.

Recent studies have shown that desertification does not have only one cause, but is a consequence of a number of natural and human variables (agriculture, animal breeding, urbanization, industrialization, and other growing anthropogenic disturbances). This study, focused on the village of Zougoungou (on the north part of the Central Plateau of Burkina Faso), gives an overview of the problem in the Sahelian area. The research identifies the policies necessary for the protection of the environment to combat and control desertification: the solution found includes a number of methods and techniques for soil and water conservation.

Keywords: Combating desertification, ethno-engineering, land management, soil conservation, water conservation, food security and active participation of the population

Introduction

The annual rainfall in the desert environment is usually very low and the rainiest period is concentrated in only two months. These seasonal rains are the only source of sweet water for the entire year; this is the reason why agriculture succeeds, surviving in the hot temperatures, only in this humid period but, with the arrival of the dry weather, the entire harvest is consumed in a short time and fresh buds are burned in a few days. The intensity of showers is so huge that the washing away, even on weak slopes, carries away plants, organic materials, minerals and superficial grounds, causing a fast desertification of the territory and the erosion of the fragile and thin soil.

In the soudanian region water erosion drastically reduces the quality of the soil. It becomes sandy and poor in nutrients and its water retention capacity is reduced due to the loss of organic materials. The soil is then eroded by the wind, sun and runoff water. This type of erosion is represented by the deflation and accumulation of sand [7]. The persistence of some traditional farming practices are major contributory factors to the degradation of natural resources, aggravated by the hazards of the climate and the effects of population and live-stock growth.

This critical situation demands the application of productive and economic solutions to improve the conditions of the rural population and realization of a program of construction of artificial water pools in the rural zones. The collection of rain water makes possible an increase of the water availability and allows, with little expense, additional cultivations. Its conservation is important because it satisfies the requirements of potability, hygiene, irrigation and watering both of people and livestock until the next season of rains. These constructions, holding the water, stop the impetuous flow of floods, allowing the rehabilitation of degraded crusted soils in the eroded and desolated lands. The collection of the rain water and the defense of the soil are realized through the construction of hydraulic systems and catch basins.

Soil and water conservation techniques

Ethno-engineering

Local communities are aware of the ecological crisis by which they are hit and of the absolute misery in which they are forced living. Already for several years the population is adopting a new spirit of conduct in the war against desertification and it has started numerous action plans. Farmers are now considered to be the potential solution to reduce the effect of desertification, rather than the problem, and so the value of local knowledge and skills is growing more and more. This involves a major focus on building farmers capacity to innovate and develop technologies appropriate to their own conditions, to support sustainable soil fertility management and soil and water conservation and to ensure long-term food security through the rational management of natural resources [2].

African cultivators apply a wide range of techniques, but in the traditional agricultural system some practices are major contributory factors in the degradation of natural resources. In fact the persistence of some inappropriate traditional practice is contributory to the degradation of environmental resources: slash and burn, nomadic herds destroying young plants, bushfires, and woodcutting. A marriage between indigenous and modern techniques may be required to increase technical efficiency [8]. Several NGOs operating in the country have developed programs to stop desertification with much greater involvement from the local communities. They provide support for farmers and this encourages the spread of those techniques.

Water and soil conservation systems were developed as a response to the increase of desertification and erosion of the landscape. These practices reflect several functions (preventing erosion, preserving organic matter, preserving properties of the soil) and they need to reduce land degradation, improve agricultural output and consequently food security.

It is a set of principles and techniques based on a whole system approach that works with natural patterns to restore or increase the depth and fertility of the soil, while increasing its water holding capabilities. It integrates terraces, ponds and cultivation techniques with the natural landscape, to infiltrate water into the soil efficiently and hold it on the land as long as possible. In order to truly work with nature, implementing a system requires careful observation and assessment of a site. Every element in a system should serve multiple functions and every function in a system is served by multiple elements. Because of the different agro-climatic regions of Burkina Faso, there is a wide variety of traditional SWC (Soil and Water Conservation) techniques that are more or less effective in the preservation and recovery of natural resources.

Water conservation

Dry-stone walls consist of a group of stones stacked together, without any concrete, so that water is filtered, but not blocked. After making a topographic survey using a «sloping triangle» or a «water level», the farmers create «terraces» by digging a furrow in which the blocks of stone are placed.

These anti-erosion sites have the effect of slowing down the water; creating a micro-climate that favors the establishment of natural vegetation after the rainy season; creating «filter beds» that enable the soil to consolidate above the walls by preventing the formation of channels [3]. This technique is widely used on slopes where it can be used in conjunction with crops. However, it can also be used with grasses such as Andropogon gayanus, as a silage for livestock, and can also be used for the manufacture of dry-glass palisades. Known also as «vegetalized» walls.

The «bouli» is an artificial pool dug at the foot or midway up a slope at a point where is a convergence of runoff. Pond placement is critical to both longevity and water holding capacity. They should not be placed in gullies because there is typically very little material available to build the dam with and they tend to fill up with silt faster. There is also a greater risk of dam failure due to the lack of a spillway. Boulis have several advantages in the landscape: the water collected lasts for 2–3 months after the rains and is mainly used for livestock and for irrigation. It's better to have several small ponds than one large pond, since the former will lose less water by evaporation. Shade and wind shelter help reduce evaporative loss from any pond; this can be achieved through hedgerow plantings around the pond. Another way to reduce evaporative loss is to increase the depth and decrease the diameter of the pond.

Restoration of lands productivity

The zaï is a technique used in the extreme north of Burkina Faso, where the average annual rainfall is very low and ground is very degraded [6]. It consists of digging pits into which organic materials are added.

The zaï is usually a hole with a diameter of 20–30 cm and depth of 10–15 cm. Their dimensions vary according to the types of soil in which they are dug, larger in lateritic soils than in less porious clay soils. The holes are above all used to rehabilitate the lateritic and sandy-clay soils. During the dry season the zaï collects the leaves, twigs and fine sand carried by the wind. Farmers also put a handful of manure in the holes to attract termites that dig underground galleries that facilitate the deep infiltration of rainwater and runoff. The termites not only improve the porosity and water retention capacity of the soil, they also bring other nutrients from the deeper layers of soil to the surface horizons and vice versa. During the second year of the zai system, the farmers sow their seeds in the existing holes or, if there is enough space between the holes, they dig new holes. The zaï practice, a very complex soil restoration system using organic matter localization, termites to bore channels in the crusted soils, runoff capture in micro watersheds, and seed hole cropping of sorghum or millet on sandy soils. Investigation on many fields of the Mossi Plateau (northern part of Burkina Faso) has shown a range of variations of the zaï system in relation to soil texture, availability of labor and organic matter, and relevance for rehabilitation of these degraded crusted soils.

Another technique is the half-moons, which are half-circles two meters in diameter and a depth from 20 to 30 centimeters. They are laid out in quincunx on slopes in order to collect part of the rainwater. A hole is dug in the middle of the half-moon to plant a tree there. This technique prevents water picking up speed and thus from eroding immense gullies. It supports the reappearance of the vegetation.

From the conservation to the management of the biomass of the soil

During the rainy season most of the herdsmen graze the livestock in the bare region of the north, where the quality of the forage is relatively high. During the dry season, when water runs out in the north, they migrate to the humid south, where livestock can graze on the crop left after the harvested agricultural plots and on the remaining green grass in the lower regions along the rivers. These flocks and herds are also a major source of manure for the cultivated land. This practice is known under the name of Transhumance.

Mulching is one of the simplest and most beneficial practices. It consists in covering the soil with a layer of dry grass (2 cm deep). During the dry periods (April and May) the farmers prepare a protective layer of a material that is spread on top of the soil. The advantage of this technique is double: during the rainy season it protects the soil from the erosion of the falling rain drops, while during the dry season, it preserves humidity and reduces evaporation. Since dry grass is made up of organic materials, it also fertilizes and attracts termites, which dig galleries in the soil to reach the surface and increase the porosity and permeability of the ground, allowing the infiltration of water.

Mulching is a practice of covering soil with a layer of material that will provide a variety of beneficial agronomic results. Mulch can limit weeds, conserve soil moisture, moderate soil temperature, decrease soil compaction and may also reduce the spread of some soil-born diseases. Mulching materials may be organic, from living sources such as wood chips, or inorganic, such as plastic sheeting. Over time, organic mulches can help build a better soil structure that pays off in healthy, vigorous plants that may be better able to live with insect and disease infestations.

The trenches are usually 200m long, 1.5m wide and 1.5m deep, and they are built to heap compost. Their dimensions vary depending on the type of soil. They are designed to produce organic fertilizer to enrich cultivable land and are widely used throughout the country. Their disadvantage is that they are fairly labor-intensive, as the composted materials must be watered and monitored to prevent the material at the bottom calcifying due to the internal heat generated. Although the technique has been mastered by many farmers, it is not widely applied due to the agricultural equipment required to dig the trench and the water required for watering.

The cultivated areas are entirely cleared and usually enclosed by planting quickset hedges. Trees are only used to protect cultivated areas from the wind, to reduce evaporation.

A barrier of deadwood around all the gullies in the field will interrupt the wind regime near the face of the field and prevent the sand from moving. Farmlands in windy regions can be protected by planting tree fences or grass belts. Sand that manages to pass through the grass belts can be caught in strips of planted trees.

The traditional agro-forestry systems use a number of advantages offered by certain fertilizing species, in particular Faidherbia albida [4]. This particular tree loses its leaves at the beginning of the rainy season, giving the sorghum and the millet enough light to grow, while still providing enough shade to attenuate the effects of interior heat. During the dry season, the tree's long root absorbs the minerals that are beyond the reach of other plants and the tree stores them in its fruits and leaves. Since the tree also absorbs nitrogen from the atmosphere, it enriches the soil and improves the crop yield. During the wet season, the fallen leaves form mulch, which enriches the arable soil and provides nourishing forage. The soil is also enriched by the droppings of the animals that feed on the leaves of F. Albida and the crop residue.

Methodology of the case study

The model was applied at the local level in a case study in the north of Burkina Faso. This study examines the adoption of soil and water conservation practices and their use in a particular agro-ecological zone in Burkina Faso. The study area chosen to develop the research is the department of Gomponsom, in the region of Passoré. The village is located between two agro-climatic regions, the Soudanian and the Sahelian one, but there is a strong Sahelian prevalence regarding climate. This bio climatic zone is characterized by meteorological and spatial variability [1].

These transition zones have very fragile, delicately balanced ecosystems. Desert fringes often are a mosaic of microclimates. Small hollows support vegetation that picks up heat from the hot winds and protects the land from the prevailing winds. After rainfall the vegetated areas are distinctly cooler than the surroundings. In these marginal areas, human activity may stress the ecosystem beyond its tolerance limit, resulting in degradation of the land. By pounding the soil with their hooves, livestock compact the substrate, increase the proportion of fine material, and reduce the percolation rate of the soil, thus encouraging erosion by wind and water. Grazing and the collection of firewood reduce or eliminate plants that help to bind the soil.

An integrated project to strengthen the development capacities of the communities analyses the sustainable agriculture initiatives. The natural resources are subject to a constant process of degradation due to climate and to the pressure of the human and animal populations.

The choice of the period (in which the analysis has been carried out, March) is motivated by two main reasons:

- To follow the difference phases of realization and installation of these constructions by the local population;

Figure 1: Representation of the vegetation areas delineated on the topographic map of 1998.

- To test whether the previous years' constructions were still holding water.

The motivations for the choice of the area are:

- All of the different typologies of construction have been adopted in the Zougongou basin;
- The area is occupied by two different ethnic groups: the Moussi, who are farmers, and the Peul, who are shepherds. They are not used to working together but they need to find an answer to their common problems of land management (which ones to use for grazing and which ones for agriculture). The farmers and the nomadic shepherds are working together to arrest the advance towards the south of the ecological limits of the vegetation fringe (border zone between desert and desert sub-formations).
- In this area all the constructions are realized under a territorial plan;
- The dialogue between citizens and technicians had the common objective of developing a sense of communitarian responsibility.

In order to ascertain the effectiveness of those constructions it is necessary to make a study of the aerial photos taken through different years. The success of these works can be measured by delineating the distribution of the vegetation and its several formations before and after their

Figure 2: Representation of the vegetation areas delineated on the aerial photo of year 2001.

realization. This is what has been done, from the analysis of the aerial photo taken during the 2001 mission and of the topographic map dated 1998, in which the vegetation areas are delineated. Their comparison shows a great increment of the vegetation over the period of three years; therefore an increment of the harvest and of grazing grounds has been achieved.

Conclusions

The soil and water conservation system described cannot be proposed as a universal solutions in so far as the ecological conditions related to the associated economic conditions are different in every country. In order to re-establish the ecological equilibrium, it is necessary to take advantage of the aboriginal knowledge and give confidence to their ancient techniques [5]. The population is not entirely defenseless against threats because it has put into practice scientific knowledge about its territory and different kinds of solutions to Natural Hazards. In this way the degree of vulnerability decreases and the risk of hydrologic deficit disaster are no longer characterized by huge damages. Such advantages provide the possibility of increasing the production of cereals and of reintroducing a large diversity of useful plants.

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The semi-arid region in Brazil

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Abstract
This article focuses on the semi-arid part of Brazil which extends into the North-East Region and into the South-East Region. Although the 30% of the population lives here, this territory is characterized by drought periods. Water collection is very difficult because of an intricate institutional network that in no way simplifies this activity. A program for water collection and preservation started some years ago thanks to the Environmental Ministry and other associations involved with this problem.

Keywords: Sertão, São Francisco, fazenda, agriculture, precipitations, cistern, women

Introduction
The Brazilian Semi-Arid Region corresponds to an area of 974 752 km^2, which extends to the North-East Region of the Country, to the northern region of Minas Gerais and Espirito Santo. It includes nine different States [2].

Vegetation
This territory, also called sertão nordestino, has a particular kind of vegetation: the caatinga, a non-homogeneous forest of cactus and mimosas, which changes according to the rains. For the most part of the year the sertão is brownish grey and bare; when the rain comes, the landscape suddenly becomes green and blooming. These low shrubs are rarely mixed with trees or higher plants, and they adapt easily to the climate characteristics of the territory: scarcity of water and high evaporation rate.

Hydrography
There are two important rivers in this territory: the most important one is the São Francisco, which at 2900 km is the longest river in Brazil; it has an average flow of 3140 m^3/s and represents 2/3 of the water available in the region. In the driest part of the valley of São Francisco, there is the Sobradinho dam, which can hold 4100 km^3 of water. It was built to produce energy and it still produces a large amount of energy nowadays. The other significant river is the Parnaiba. It has its source in the Serra da Tabatinga; it is 1715 km long and has a large number of tributaries. It is navigable for 760 km. Another river passes through the semi-arid area, the Jequitinhonha; it is not particularly long, but is very important for the populations that live in its valley [2].

Figure 1: Map of Brazil

Politics and territory

The policy in this territory and in the other rural areas of Brazil depends a great deal on the previous Portuguese colonisation. During this period the territory was divided into fazendas, areas distributed among rich foreigners such as nobles or traders. The fazenda gave a piece of land and a place to live to the poorest people in that society, to slaves and to freedmen in exchange for work, loyalty and obedience. The fazenda was the center of the power in the community: the boss, called also coronéis, was rich and he was the only one who had the possibility to study and to receive an education. He was the person who could promulgate laws. Farmers and camponeses, the autonomous cultivators who managed the land on a familiar level, were completely subordinated to the coronéis. However, they slowly gained consciousness of themselves, of their work and finally achieved their independence [7].

Colonialism ended a long time ago, but if, formally, the political situation has totally changed, the real conditions in the rural areas of the semi-arid region seem to be the same. The fazenda has been replaced by the large landed estate and rich landowners have the same role the ancient coronéis had, and they can also stand in the political elections. They use water as a political instrument despite UN conventions: during drought periods, if the population is loyal to them, they help people by means of caminhões-pipa, tankers full of water, even if water in Brazilian law is considered as a common property. Landowners do not pursue long-term projects to maintain their power and therefore fail to discover a definitive solution to the water problems present.

Agriculture

During the 70s a rapid development of intensive agriculture took place. In the cerrado, the cultivable lands, the cultivators did not have any documents attesting their property, but they followed consuetudinary norms. Rich landowners, helped by corrupted administrators, bought all these lands, paying a very small price for them. Poor people were also deceived by the perspective of new jobs and the development of the local economy. The typical crops of the territory have been substituted by other more profitable monocultures such as the eucalyptus, useful for the iron and steel industry and for the paper mills.

This plants require more water (about 7 l/day in contrast with the 1–2.4 l/day consumed by typical plants). This irrigation, which requires a lot of electrical energy and a copious quantity of water, causes soil salinisation. Added to this, the fertilizers used, which contaminate the soil and the aquifers, make all new cultivations incompatible with the characteristics of the sertão.

In the São Francisco basin the situation is even more serious because of various conflicts linked to the different water usages: the water demand for irrigation increased and reached 27% of the river flow.

Brazilian politics on water resources

The Brazilian territory is huge and problems related to water are different and innumerable. Therefore it is indispensable to have ideological and legislative bases to manage this precious resource.

In the Federal Constitution of 1988, water is declared a public good: no single state can manage water resources alone, without involving the others, without dialogue or discussion.

There are three fundamental principles governing Brazilian water politics:

- sustainability, to guarantee a use of water resources compatible with the natural cycle of water;
- precautionary measures to preserve water quality and quantity for future generations;
- the manifold usage of water in order to have a rational and integrated use of resources.

The Codigo de aguas was the first water regulation at national level. This norm was changed only in 1997 with the promulgation of the National Law on Water Resources n. 9.433, inspired by the principles of Eco-92 and Agenda 21 [6].

This law can be explained briefly in 6 points:

1. water is a common and public good
2. water is a natural and limited resource and it has an economic value
3. in drought situations, water resources have to supply human needs first
4. the manifold usage of water is the guideline of water management
5. the basin is the area in which the National Politics on Water Resources has to be developed
6. water management has to be decentralized in order to assure the involvement of public authorities, users and communities.

Water shortage in the semi-arid region

In Brazil the Semi-Arid Region has particular characteristics that differ from those of the other semi-arid regions on the earth. Rains are abundant, about 700 mm/year, 36 billion cubic meters of water, a normal quantity of rainfall in an Italian city. The problem is the concentration of these rains in a season which lasts for only a few months, sometimes only for one month, not to mention the bad distribution of these pluviometrical precipitations between the different localities. In some areas the precipitation level reaches only 200 mm/year, and the majority of the territory suffers from drought during a large part of the year.

Water deficit also has other different origins: high evaporation rates (about 2500 mm/year) and high temperatures contribute to less available water; wind, scarcity of vegetation and water shortage of permanent rivers are other problems that make this situation even worse. Also the lack of technology, which limits water gathering and preservation, represents one of the critical points that the government has to face.

There are some conditions and restrictions in water resource usages, such as the vast surface of the semi-arid region in opposition to the small area characterized by fertile soil and good topographical conditions and to the small area enjoying favourable weather conditions. The lack of large rivers on which dams could be built is one of the reasons for the shortage of hydro-electrical potential.

This multifaceted situation leads also to social problems, such as the limitation of human activity and the low development of the productive sector.

Focus on Jequitinhonha basin

About 900 000 inhabitants live in the Jequitinhonha valley. They are organized in rural communities. Corn, manioc, sugar cane, beans, bananas, mangos and pineapples are cultivated at a domestic level. In the last 25 years, water availability in this territory has fallen to about 60% of its original level. This is due to weather changes and to new crop cultures. The soil is not productive anymore and the communities have to move to the grotas, small and low fertile lands.

Water management in the Jequitinhonha valley is regulated by consuetudinary norms. These norms try to minimize the waste and to optimize the usage. For example, people can use agua fina, the spring water, only for human needs and for irrigation; other necessities are supplied by running water, which is considered impure. There is no public politics aimed at treating the problems of water scarcity in order to improve the living conditions of families [3].

Figure 2: Semi-arid landscape

P1MC (Programa 1 milhão de Cisternas)

In 2001 the Environment Ministry and the ASA (Semi-Arid Region Articulation, a network of more than 700 organizations) decided to begin the Formation and Social Mobilization Program for Living with the Semi-Arid Region: One Million Rural Cisterns_ P1MC. With this program it will be possible to construct one million cisterns in 11 Brazilian States. Also the international Committee for the World Water Contract takes part in this project, which also involves some NGOs. The CeVI (Centro di Volontariato Internazionale- International Voluntary Service Center- with its seat in Udine) represents the Italian Committee and it is charged to collaborate in the project in the State of Minas Gerais, in the Jequitinhonha valley. The part of the program managed by CeVI has three sections:

1. to provide an education for the local population regarding the social and environmental characteristics of the region, in order to gain a clear perception of the problems involved
2. to increase the access to water resources thanks to the building of cisterns
3. to improve water management in order to preserve the actual resources [4]

The cisterns

Rainwater is caught from the roofs by means of pipes and is preserved in the cisterns, which are the best way to minimize the evaporation. Each water reservoir has a capacity of 16 000 l, a sufficient quantity of water to support one family's needs during the dry season. Cisterns — made of pre-molded plates — are built by local people, and specialized bricklayers convey technical know-how [3]. The project will last for 6 years with an investment of about 321 725 301 Euros. P1MC's principal aim is to involve citizens and communities in water management and to experiment with new sustainable models of water administration. By September 2005, 100 000 cisterns had been built [5].

Figure 3: The cistern for collecting rainwater (in the background, right of house)

Figure 4: Women's role in water supply is crucial

The Role of women in the project

In rural civilizations women have always had an important role to play and their relationship with the world of water has always been very strong [1]. They find the sources of water, they transport the water to the villages walking for kilometers with containers on their heads, and they have accumulated a vast experience in source protection, in water purification, treatment and preservation.

The project tries to bring out the values of women making them work in the most important phases of the program, such as the educational and the economic sectors.

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English travellers on the Rhine River during the Romantic period 1790–1850

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Abstract

The Rhine River and its picturesque valley were one of the first mass tourist attractions in Germany during the 19th century. English travellers were the first to enjoy the stretch between Koblenz and Rüdesheim/Bingen up to Mainz. This is precisely the area that was deemed the Cultural World Heritage of the Mittelrheintal in 2002. This thesis states the very historical as well as unique philosophical approach to the phenomenon of the development of a tourist destination during the period of industrialization and romanticism. Furthermore, it states the Socio-Economic Impacts on both foreign travellers and on the local population along the Rhine River in the early 19th century. As a participant from Johannes Gutenberg University in Mainz coming all the way from the Rhine River to Seville, I enjoyed hearing the stories about the rivers of Andalucia, and was able to participate in the extensive studies of contemporary water management and also the Water Framework Directives of the European Union. It was a great pleasure and unique experience to be able to hear about the methodologies, problems and solution statements outlined by the Department of Human Geography of the University of Seville. The possibility for interdisciplinary participation in the Erasmus IP 2006 Geography of Waters and the field work enabled me to follow one of the main tasks and methods of cultural anthropology: participant observation. It became a reality to study given tasks in the wide field of geography and even simultaneously to observe the participants and their methods from an anthropological point of view as well as sharing the feelings of our Spanish hosts about their own river, the Guadalquivir.

Keywords. English travellers, the River Rhine, first mass tourism, philosophy and attitude, travel and transportation, tourist destination, art and literature, tourist guidebooks, travelling as purpose, new era, prospects, eco-tourism, European river regions

Introduction

Lord Litton, Pilgrims of the Rhine: «The descriptions of the Rhine have been considered by Germans sufficiently faithful to render this tribute to their land and their legends one of the popular guide-books along the course it illustrates, – especially to such tourists as wish not only to take in with the eye the inventory of the river, but to seize the peculiar spirit which invests the wave and the bank with a beauty that can only be made visible by reflection. He little comprehends the true charm of the Rhine who gazes on the vines on the hill-tops without a thought of the imaginary world …» Lord Litton. (Lord Litton, preface IX). [14].

English travellers of the early 19th century were the first ones to discover the beauties of the River Rhine valley. Therefore, the «Romance» of the River Rhine and its valley as a tourist destination for foreigners at that time did not originate from the German movement and attitude of the «Rheinromantik»[6] and the famous German writers and intellectuals such as Clemens Brentano, the Brothers Grimm, Friedrich Schlegel [21] and others. It is important to distinguish and explain the motives, movements, attitudes and historical conditions which prevailed in England at that time and led to the birth of a new tourist destination on and near one of the most famous rivers of Europe: the Rhine.

From philosophy to attitude

Romanticism

In Europe, the meaning of the word «Romantic» varies from country to country [20]. It is a term that should be felt rather than defined [7]. The historical «Period of Romanticism» has been continuously debated by scholars and critics. The term «Romanticism» seems to mean so many things [7, 20], and its literary studies are even linked to cultural geography [4]. That is the reason why it is important to divide the term between what it meant in Germany and what its meaning was for England during the 19th century.

On the continent, the period between 1790 and 1850, comprising only 60 years, was called «the period between the two revolutions» and respectively the »Romantic period.» However, when referring to «arts and literature» and «architecture and landscaping,» the time period is longer from 1750 to 1850, an entire century. As the so-called Neoclassicism favoured the style and the philosophy of the Ancient Greeks, these are combined with the ideas of common sense in order to avoid sumptuous styles such as those found in the Baroque churches of Bavaria. Therefore the architectural style of this period is simpler. British buildings and houses of that period are an example of geometrical architecture combined with classical columns [11]. The term «Romantic» or «Romanticism» should not solemnly be attached to style, but rather be understood as a philosophy or attitude of its time.

The period of the Romantic in Germany and England

In Germany, the so-called «Rheinromantik» is more likely to be the period from 1790 to 1830, based on the political changes in the early 19th Century in Europe. The term «Rheinromantik» became popular in 1802 [24] and should be understood as an opposition movement to the Age of Enlightment (Rousseau, French Revolution). The individual, his feelings, and the collection of German Songs and Fairy Tales by the Brothers Grimm and their friends Achim von Arnim and Clemens Brentano define this period in the area of literature. The vivid myth of medieval times combined with rebelling poets and a new idea of Germany as a cultural nation provided a common attitude. «Rheinromantik» is an artificial construct linked only to the landscape of the River Rhine and its surrounding region. This period is not a historical movement!

Conversely, in England the term «Romantic» refers to the times of King Arthur, his knights, and the tales and sagas of that time. They were called «Romances» [11]. This is how this period of the 19th century got its name in England. The merry medieval times were remembered for the return to the values and beauty of that time. The typical landscapes were the Lake District and the Cumbrian Mountains in Northern England, where the first English tourists began to spend their time in the late 18th century because of its landscape, castles, ruins and nature, although it had been a poor and isolated region before then [10]. The tourists took these typical «English» pictures that they had in their minds as being something romantic or picturesque, and transferred these identical images to the landscapes of the Rhine River [24]. English travellers wanted to plunge into romantic landscapes and experience them [22] as if they were diving into a painting by famous painter William Turner. One could understand it as not living in a box, but living in a picture! The picture he had in mind was what the English Traveller was looking for on the Rhine River. He wanted to live, experience, and feel it.

Gothic revival

A literary impulse can be seen as the true starting point of the Gothic revival in architecture. During the Romantic period, buildings were made with Gothic arches and shapes (Fig.1). In England, artificial ruins were built in newly conceived landscape parks with little temples and waterfalls [11]. The English liked to «look with pleasure at things of a certain shape and character [5]» and appreciated the high towers [24] of Gothic churches as being something sublime [11] or something higher that was reaching for the sky and at the same time so mystic and sophisticated – simply «aesthetic delight [5]».

In literature, the desire for «the picturesque,» the love of picturesque scenes, buildings, and even rocks caused melancholy, and, yet, sublime enthusiasm. Feelings were so important at that time. Feelings about power, love, or even cruelty occurred at the same time [6]. Feelings for the Antique Greek, Medieval Centuries, and Gothic Architecture were seen in the then bestselling novels and horror stories of the female British author Ann Radcliffe. Therefore architecture, literature, poetry, painting and also philosophy influenced each other during this period of revival. This mixture of interests and movements created a new travel trend: «picturesque touring [22]».

The Rhine – seeing is feeling

From 1790 to 1830, female writers were especially successful in the literary market [20]. Writers who did not have much in common were grouped in so-called «schools.» Many of these writers wrote in a fashion similar to the famous English female author, Ann Radcliffe (1764-1823), and were thus referred to as members of the Radcliffe school. They often imitated her Gothic style [20].

No one alive at that time would have thought of their age as the «Age of Romanticism.» [20].

Figure 1: The pilgrims of the Rhine, 1834, by G. Bulwer Lytton [24]

This term was applied much later; they used the words «romantic,» «picturesque,» «pleasure of imagination,» etc. instead of the term «Romanticism.» «Romanticism» at that time was a broad cultural phenomenon. It was a new spirit, a return to nature, and a «new sympathy with man» [1, 20]. In Germany this age of sensibility might even go back to Goethe's «The Sorrows of Young Werther,» which he had already written in 1774 [23, 25]. This period is, however, generally known to have ended in the 1830s.

In England, Romanticism and Gothic Revival where based on the sublime [20]. The conquest of the Alps by the first British tourists can explain what the sublime represents. Seeing and conquering the highest mountains made them feel much more than mere mortals [23]. But their thoughts go back to their own British places of interest. In 1769, the Lake District's Cumbrian Mountains were discovered as a tourist destination, and after 1776 many guide books to the Lakes were published [18]. Day travellers with their picnics followed some sentimental travellers and explored the landscapes to enjoy the shadows of half-ruined abbeys, and they admired the buildings with Gothic arches. The Gothic construction had an overwhelming emotional effect on the spectators. But the British did not like the fact that the Gothic style originally came from France. They called it a «mystery.»

English writer Ann Radcliffe was understood to have written about the sensibility of man, and «the natural goodness of man away from the corrupting effects of society [23]». She called the Rhine River, the cities and vineyards picturesque and pleasures of the imagination. The main characters in her books showed strong feelings towards man and nature. For example, her female protagonists were often «sighing, blushing, weeping, and fainting [23]» when they saw nature and its beauty. These women also acted similarly when they were on the Rhine River. This «Sensibility was not just a literary movement, it had a cultural effect on the lives of men and women across Europe [18]». It created new gender roles, and English middle class families offered their wives and daughters a similar aristocratic social position [24]. This created a feminine world of leisure, beauty, literature, and travel. This literary movement helped a new social class to emerge from their limited viewpoint and become the strong and established class of English travellers to the Rhine River.

In 1791 Ann Radcliffe published the first of her so-called «horror stories,» «Romance of the Forest,» and in 1794 she published her second work, «The mysteries of Udolpho.» It is an amazing fact that she wrote her first two books at home without actually having seen the nature, castles and ruins of her fantasy. It was not until 1794 that she took her first trip to the Cumbrian Mountains in Northern England [25]. That same year she made her first trip to the continent and wrote the book «A journey Made in the Summer of 1794 through Holland and the Western frontier of Germany,» published in 1795. She describes the Rhine and the city of Mainz that had been destroyed by a fire and invading French troops.

Radcliffe. A Journey …: «On the quay there is some appearance of traffic, but not much in the city; so that the transfer of commodities from vessels of other districts to those of the Electorate (Mainz) may be supposed to contribute great part of the flow near the river.».»…it is apparent that Mainz could not have been important as to commerce.»Radcliffe. [19]

Radcliffe. A Journey …: «The bridge of boats over the Rhine which both in peace and war is so important to the city, is now in a much better state than the French found it, …»Radcliffe. [19]

Her descriptions are not solemnly romantic. They tended to exaggerate or praise the sublime, but she also described very well the details, as in the city of Koblenz.

Radcliffe. A Journey …: «The voyage requires nine or ten minutes., … The old place of Ehrenbreitstein deserted because of its dampness. It is a large building, even more pleasantly situated than the new one, being opposite to the entrance of the Moselle into the Rhine.» Radcliffe. [19]

Karl Baedecker (1801–1856) was born in Essen, Germany, studied in Heidelberg and worked in a bookstore. In 1827 he opened his own bookstore in Koblenz. His first Guide «Rheinreise von Mainz nach Köln» became famous as a conversation book for travellers. More books on different countries would follow. In 1846 he copied the red cover of the guide book, since John Murray (the English Baedecker) had used it in England. They were competitors, but at the same time they were friends. In 1855 his last book was published about greater Paris. In 1859 Baedecker died in Koblenz, but his grandchild continued the family tradition of publishing guidebooks.

Baedecker proved to be very innovative and was recognised as the premier German guidebook writer of his times. He was very attentive to detail. Legend states that he counted peas from his jacket pocket into his trousers while walking up stairs in order to have the number of stairs at the end of the staircase, and he would enter this information into his book about that establishment. His travel guide books gave hints for guesthouses, restaurants, the cost of accommodation, distances, sights to see, historical buildings, pictures, city maps, and geographical maps, and schedules for steamboats and trains were published. This handy guidebook, which was originally intended to fit in men's jacket pockets, did not change its function or size and appearance. It was meant for the educated citizen, the «Bildungsbürgertum» of the 19th century, and the red book is still a bestseller today.

Tourism

The Grand Tour

During the 17th and 18th centuries, young aristocrats who were considered the pioneers of modern tourism were travelling around Europe. This form of travel to the famous classical sights in Italy, France, Greece and other European countries became the model tour for generations to come. The aim of their travels was to combine the visiting of antique sights with contact with foreign courts and aristocratic families in order to learn and understand foreign lifestyles, etiquette, and diplomacy [6, 24]. Their status enabled these fine young men not only for education, but also for enjoyment and amusement in good company. They got to know the «savoir vivre» of their times [9].

During the later British Romantic period, travelling authors liked to put their poetry «in a concrete geographical context complete with maps, walking guides [18]», exact descriptions of nature, buildings, waste or agriculture and specific images of mountains, lakes, and rivers. There are plenty of texts from that period about the natural environment. The Romantic idea of nature contributed a great deal to a holistic approach and to an understanding of the natural world. British Romantic poetry was the first literature with biological conceptions [18].

Figure 2: Ideal River Landscape, 1788, by Christian Georg Schütz d. Ä. [26]

Due to the Gothic Revival, the end of nature was described as «a nightmare vision of the Earth threatened by imminent environmental catastrophe [18]», global apocalypse, flooding «as depicted in Genesis [18]», and all of this was a result of normal human activity. The reason given for this nightmare vision was the fact that during the early years of the 19th century, the manufacturing cities of England were filled with smog and were the base for mass production [18].

George Lord Byron (1788–1824) was one of the most famous authors of the English Rhine Romantic Period. His epos «Child Harold's Pilgrimage» (1812) deals with a young man on his way to Waterloo during the Napoleonic Wars. Byron was the only British author of his times with a weakness for the French Emperor [15]. On his journey, Harold describes the beauty and virginity [6] of the Valley of the Rhine River. This bestseller story was the root cause for many English travellers to visit the Rhine [24], and to particularly enjoy the stretch between Koblenz and Rüdesheim/Bingen up to Mainz. On the one hand, British authors described the destruction after the French war in the Rhine valley, but they also romanticized everything that they saw. They even described the destroyed castle of Ehrenstein close to Koblenz as «a bright stone of honour.»

In the 19th century, most leaflets, prospectuses, and books about the history of the Rhine contained the 3rd verse of Byron's «Child Harold`s Pilgrimage,» the castled crag of [4]. Byron died in 1824, and all of his works were published by John Murray. Murray was known as an expert on English travel guide books. In Germany, however, Karl Baedecker became the most famous editor of travel guides.

Figure 3: Robert Andrews and his wife, 1748-1750, by Thomas Gainsborough [11]

Another Englishman, painter and artist William Turner (1775–1851), also conducted his Grand Tour to Europe and paid tribute to the Rhine. Born the son of a barber, he became a student of the Royal Academy in London, and later even became a professor at this distinguished academy. His water-colours and other paintings were exhibited in the Royal Academy from 1790 until 1837. In 1817 he took his first trip to the Rhine. He stayed in the area for four weeks and took pencil sketches of the city of Mainz. [12]. His paintings remind us of the early impressionists due to his colourful style, which was unusual for that time. Being a romantic, Turner wanted to experience himself the gravity and power of nature. Legend states that he tied himself to the mast of a ship in order to suffer a storm. Afterwards, he sat down at his canvas and painted his views of that memory. Turner was famous for his so-called «curry colours [12]», warm yellow and red orange [11], which he obtained by painting on blue and beige instead of white canvas [12]. His style was revolutionary compared to the traditional style of Thomas Gainsborough [3].

Gainsborough's picture shows a stiff country lifestyle portrayed in 1750. Unlike Gainsborough, Turner's picture of the ocean, «The slaveship,» [Figure 4] captures the drama of nature. The drama exists between the light and natural powers. Human beings and animals are painted very small and in detail, but colours of impression prevail. Turner applied similar watercolours and techniques to all his sketches taken on the River Rhine and in Mainz. Back in England [12], he converted them into famous paintings [3] which increased the longing of their English spectators to travel to the colourful world of the romantic Rhine valley in Germany [24]. Turner was conscious of the geographical and historical importance of the river, and always started his travels well informed [12]. This was the very way art contributed a great deal to a new movement and touristic destination.

Figure 4: The Slave Ship, 1839, by William Turner [11]

Travel and transportation

In the 18th century, transportation was a cumbersome procedure, and took place by coach. This means of travel was later followed by much more comfortable means of travel such as trains or steamboats. During this same period, England grew to approximately 10 million inhabitants, of which nearly one million were living in the city of London, exposed to the phenomenon of modernization as well as social stress [8]. The industrial cities were Liverpool, Manchester, Leeds, Sheffield and Birmingham, while the primary harbour city was Bristol. The majority of the population, however, lived in the countryside. The English gentry preferred the countryside as well, and single families resided in little towns of only three hundred inhabitants or less. The gentry families visited each other, their relatives and friends during the summer months, and some spent their time at the seaside in the city of Bath. Ladies spent their time writing letters and reading, and enjoyed dancing, receptions, and theatres [13].

In the 19th century, the so-called Grand Tour was no longer limited solely to aristocrats. Young men of the gentry started exploring the continent for one year, and some for as long as three years. Their travels included the countries of Italy, Greece, France and Germany. These «connoisseurs» knew about literature and described the landscapes as being picturesque, especially the Rhine River Valley in Germany. Their translations of texts, books and travel stories greatly helped in making the Rhine River famous in England [6, 24].

After the Napoleonic Wars in 1815, the English once again travelled through the Channel to the Continent. They started from their homes by horse. At the time, the speed of a horse was only seven miles per hour or about 10 kilometres per hour [6], and horses were the only means of land transportation. A one day trip took them approximately 28 miles or 45 kilometres with two horses with two hours rest between each stage. To slow their travels even more, the condition of many streets was too poor to permit faster travel.

Instead of travelling on horseback, it was possible to book a seat on a stagecoach that was pulled by four to six horses. Most stages held six passengers, with room for many more in a basket behind the coach, or they could sit on the roof. Women preferred the mail coach, which held a maximum of four passengers, a driver, and a lookout with a gun. In 1764, it took almost 13 hours to travel 116 miles or 186 kilometres from London to Bath. The third choice of land transportation would have been a «Chaise» for only 2 to 3 passengers. These were the first «packaged tours», as the guesthouses were booked together with the coach and the driver. This was more expensive but also safe for women travellers. Not all coaches had adequate space for large suitcases or boxes. Therefore, the so-called «Beichaise» took the heavy luggage and transported them to the destination [17]. Travellers were often robbed on the way to or in guesthouses, yet England was reported to have better roads, guesthouses, and services than Germany. From the English harbours, the tourists took boats and other types of vessels to travel to Holland then on to the Rhine River.

Welcome at the Rhine

For the Germans living along the river, the English and their keen interest in and their taste for the sublime, ruins, nature and its strength, as well as history, legends and medieval poetry seemed quite strange. The «Rhinelanders» were, however, customer-oriented, and understood how to make money out of the romantic feelings of the English travellers about the Rhine River and its valley [27]. As it was often only a seasonal business, English travellers were very welcome as paying guests [24]. Hotel, boarding-house and restaurant owners, as well as tour guides and shippers, competed with each other for English tourist money. Tour guides or transporters picked up the travellers from landing stages or train stations and recommend pensions and guesthouses, while collecting tips from both the tourists and the owners of the accommodation [24].

The innkeepers or hosts exploited guests and employees alike. Personnel were not paid and had to live on the tips given by the tourists [24]. The guests were not served if they did not tip the waiters in advance. Complaints about dirty rooms, small beds, and the typical German feather-beds, which seemed much too warm for the English during summer, were very common. The English, in turn, preferred simple guesthouses in small villages, since they were clean and inexpensive [24]. Overbooking was very common, and travellers sometimes had to sleep in the taproom of a pub or guesthouse.

Steamboats and mass tourism

In the early 19th century, the most important invention to increase mass tourism was the invention of the steam engine by James Watt. The first river boat began operation in 1817. By 1827, the first German steamboat company, the Preussisch-Rheinische Dampfschifffahrtsgesellschaft,

Figure 5: Steamboat with English travellers on the Rhine, 1875, by Benjamin Vautier [24]

operated steamboats between Cologne and Mainz [24]. The trip had earlier taken two to three weeks by sailing boat, but with steam powered boats the journey took only 83 hours (just over one week).

At the advent of steamboat tourism, heavy competition lowered fares, attracting more travellers to the river. However, the service provided by the steamboat companies declined. The captains of the boats started racing and made dangerous manoeuvres in order to be the fastest transporter. They even omitted some landing points in order to be the first at certain harbours [24]. In 1853, the two German steamboat companies merged into the white navy KD, Köln-Düsseldorfer, steamboat company [24]. Their ships were comfortably equipped, had trained personnel and enjoyed an excellent reputation. Nearly 120 passengers could travel on these boats, which were 5 meters wide, 1.25 meters below the water line and 35 meters long [24] (Fig. 5). In 1827 German steamboats transported more than 33,000 passengers, and in 1844 that number had increased to 600,000 passengers per year [24].

Travelling on the Rhine

«Summer night on the Rhine» (Fig.6), an 1862 painting by Christian Böttcher, represents the romantic views and good company on evenings spent with friends, students and other guests in wine restaurants along the Rhine. Local food specialities, regional wines and music were the goal of the tourists who ventured to the River Rhine.

Travel beside and along the Rhine has changed over time. Modern times with steamships had conquered what used to be the domain of sailing boats and towpaths along the shores. Steam

Figure 6: Summer night on the Rhine, 1862, by Christian Böttcher [24]

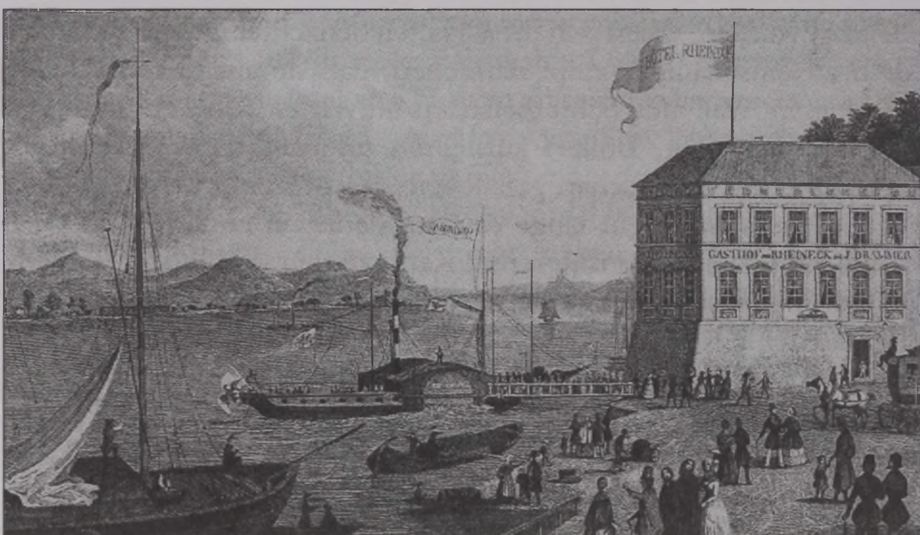

Figure 7: Steamboat «Concordia», 1827, unknown caricature [24]

power and motors helped gain travel time. They enabled tourists to travel comfortably and to see the maximum of sights in the minimum amount of time. The trip combined different destinations along the river. Daily excursions originating from one base location became very popular at that time. The greatest achievement for tourism, however, was the fact that travellers were no longer dependent on the natural water level or on the prevailing weather and wind conditions. In addition, railroad construction took place along both shores of the river, enabling travellers to choose and combine means of transportation [6]. Travelling became the purpose [2, 24]!

The following caricature showed how the British saw themselves as English Tourists on the Rhine River.

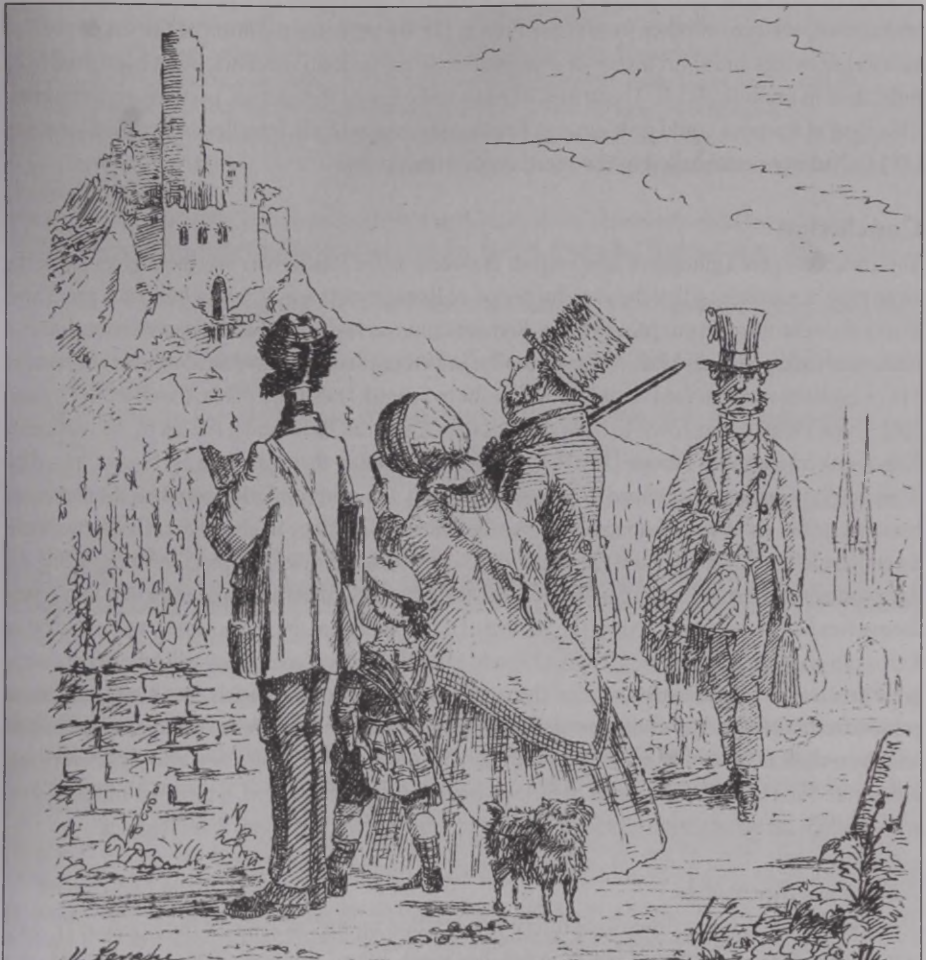

Figure 8: English travellers in front of a ruin. Caricature by V. Stoltenberg Lerche [27]

This caricature shows English travellers as they were seen by German caricaturists: dressed in stand-up collars and chequered clothing. Often they were also portrayed bringing their own seat cushions, as well as the obligatory tea with them, or carrying telescopes [6].

The British tradition of the single print of satirical drawings and short texts also became very popular in the early 19th century. These satirical prints were originally designed for the less privileged classes and were very successful in the English Press, such as the British «Punch» [6]. They could be seen in windows of publishers or other shops, and could be purchased for a small amount of money. Much of British Romantic caricature was humorous, yet was also nationalistic and anti-republican, in other words anti-French [3]. By 1830 this tradition of the single print of satirical drawings and short texts was disappearing from the shop windows, but it continued to be published in periodicals [3]. The British liked to make fun of themselves, particularly as tourists. This kind of humour could only emerge because the image of the traveller, later called «tourist» (1844), had been established in the social consciousness [6].

Conclusion

This caricature gave a glimpse of how English Travellers on the Rhine River saw themselves [6]. At the same time, it reminds us that the eventful period of Romanticism was two hundred years ago. These events also echo through our present times. Romanticism was understood as the answer to revolution, a new age of feeling and mankind. Today we also live in a «time of revolution.» Just remember »September 11» or even the more recent events like the bombs in Spanish trains and public transport in England [20]. These events have proven to be as potent as the American Revolution, the fall of the Bastille, or Napoleon's conquests in Europe [20]. We will always remember them as major events and tragedies. Thus it is important to look ahead to a possible new era. The next revolution could be another era of romantic travel and tourism along a river like the Rhine in Germany or elsewhere. This view should be entirely left to the reader's own imagination and grounded in scientific judgement regarding the development of the rivers of Europe. Periods and developments can remain unique, or they may repeat themselves like fashions and styles. The pattern of development of the rivers of Andalucia and other European regions as well as the UNESCO World Heritage Rhine River Valley will take depends to a great deal on the consciousness of all of the parties involved, such as officials, locals and possible or prospective visitors and also tour operators. The most important tasks are environmental protection and the revitalization of the waterways. Only then can eco-tourism bring a new era of discovery and enterprise. Then history could repeat itself, local traditions could be revived, reinvented and combined with modern marketing strategies for the touristic benefit of the European River Regions.

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The 10th European seminar on the geography of water Seville, Spain. June 26–July 6, 2006

List of participants

University	Participant
University of Cagliari, Italy	Dr. Andrea Corsale Dr. Monica Iorio
Linköping University, Sweden	Prof. Dr. Geoffrey Gooch
Johannes Gutenberg University Mainz, Germany	Prof. Dr. Volker Heidt Dörte Netzer Susanne Sembacuttiaratchy Philipp Wolf Christiane Geissler
University of Padua, Italy	Sara Ariano Nadia Carestiato Chiara Pasquato Cristina Sivieri
University of Pecs, Hungary	Prof. Dr. Istvan Fodor Janos Csapo Amade Halasz Tibor Pecz Levente Ronczyk
Charles University in Prague, Czech Republic	Dr. Milada Matouskova Dagmar Chalupova Sylva Rodlova Vaclav Sipek
Sofia University St. Kliment Ohridski, Bulgaria	Prof. Dr. Daniela Zlatunova Lyubomir Filipov Teodora Kaneva Kliment Naydenov Kosyo Stoychev
University Jean Monnet, Saint Etienne, France	Prof. Dr. Thierry Joliveau Yohann Benmalek Fatou Mar Ndeye
University of Tartu, Estonia	Dr. Jüri Roosaare Dr. Arvo Järvet Dr. Antti Roose Edgar Sepp Eva Liivak
University of Udine, Italy	Prof. Dr. Franca Battigelli Dr. Andrea Guaran Luigina di Giusto Meri Mauri

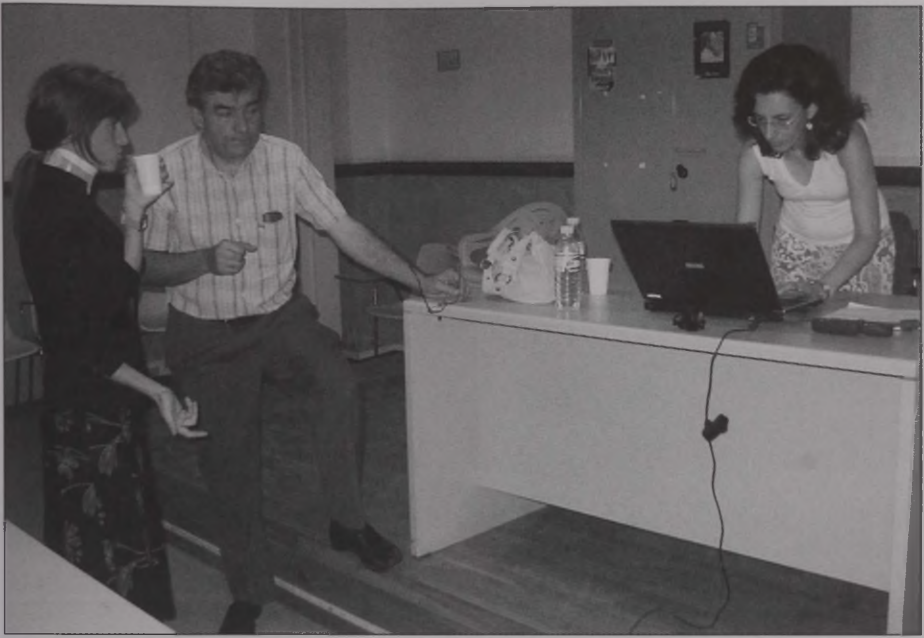
Programme

25th June, 2006	Arrivals and accommodation
26th June, 2006	• Opening session: prof. Juan Luis Suarez, dr Belen Pedregal, dr Antti Roose • Participant Universities' presentations • Poster session • Field work: recent urban transformation and the reallocation of the Guadalquivir River in Seville
27th June, 2006	• Lectures: – topics presentation: prof Leandro del Moral – regional geographical context: prof Monica Aguilar – drought management: Luis Babiano – agricultural uses: prof. Pepe Miranda, Consuelo Giansante • Poster session
28th June, 2006	• Lectures: – Water framework directive: prof. Leandro del Moral – Impacts and damages of water bodies: prof. Pascual Riesco • Visit to the Guadalquivir River Basin Authority • Working group sessions
29th June, 2006	Field trip to the west coast – Donana, coordinators Victor Garcia – Educa Verde; Ana Villa – Donana 21 Foundation; Ismael Vallejo – USE
30th June, 2006	Case study – Guadiamar river restoration, coordinators Rafa Baena, Inmaculada Guerrero, Belen Garcia
1st July, 2006	Field trip to rural areas near Ronda
2nd July, 2006	Field trip to rural areas, Cuevas del Becerro
3rd July, 2006	• Field work: 1) Drought management – EMASESA 2) River restoration – Guadaira case study 3) Agricultural uses, CAP 4) WFD, CENTA • Working group sessions
4th July, 2006	• Visit to the Seville's port • Working group sessions
5th July, 2006	• Presentations of working group sessions, discussion • Official conclusion of the IP • Dinner and cultural program
6th July, 2006	Departures

Photographs

Main building of *Universidad de Sevilla,* former *Real Fábrica de Tabacos,* built by the engineer Van der Beer during the reign of Fernando VII. The University is officially established in 1551. 57 000 students and 4155 lecturers (2005). The main building was study campus of the seminar 10th European Seminar on the Geography of Water, under the title «Water management in the South of Spain. Managing Drought and Water Scarcity in Vulnerable Environments», 25th June–6th July 2006. Photo by Antti Roose

Participants of the 10th European Seminar on the Geography of Water at *la Finca Algaba de Ronda,* July 2nd, 2006. Photo by Edgar Sepp



The organisers of the seminar, Belen Pedregal Mateos and Leandro del Moral Ituarte (from right) at the introductory lectures. Photo by Antti Roose

Lecturers and students discussing at the afternoon poster session, June 26th, 2006. Photo by Antti Roose

The field survey to the active dunes at the Doñana National Park, guided by Ismael Vallejo, June 29th, 2006. Photo by Edgar Sepp

Ronda, the destination of weekend field trip of the seminar, is one of Andalucia's interesting towns, stands on a towering plateau in the mountains of Malaga Province. Ronda is famous for the plunging river gorge which divides the medieval from the 18th century parts of the town (seen at photo). The gorge is known as «*El Tajo*», the Cliff and is spanned by a stone bridge, where this photo is taken, July 1st, 2006. Photo by Antti Roose

Panorama of the Seville from the top of Giralda tower, the Seville's Cathedral. Photo by Edgar Sepp

Flamenco at the cultural programme in Seville, July 5th, 2006. Learning the basic steps was the must for all participants of the seminar. Photo by Antti Roose

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