Project no. **GOCE-CT-2003-505540**

Project acronym: **Euro-limpacs**

Project full name: **Integrated Project to evaluate the Impacts of Global Change on European Freshwater Ecosystems**

Instrument type: **Integrated Project**

Priority name: **Sustainable Development**

Deliverable No. 12

WP2. Climate-hydromorphology interactions through changes in land-use and discharge: review of information relating selected study catchments across Europe

Due date of deliverable: **1/02/05**
First submission date: **1/02/05**
Actual submission date: **25/02/05**

Start date of project: **1 February 2002** Duration: **5 Years**

Organisation name of lead contractor for this deliverable: **CNR-IRSA**

Revision: Final

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level (tick appropriate box)		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Integrated project to evaluate impacts of global change on European freshwater ecosystems

EC contract nr. GOCE-CT-2003-505540

12th deliverable, due 25/02/05, entitled:

WP2. CLIMATE-HYDROMORPHOLOGY INTERACTIONS THROUGH CHANGES IN LAND-USE AND DISCHARGE: REVIEW OF INFORMATION RELATING SELECTED STUDY CATCHMENTS ACROSS EUROPE

Compiled by Carlotta casalegno[16], Andrea Buffagni[16], Karel Brabec[26], Jochem Kail [4], John Murphy[3], Thomas Ofenböck[15], Carmen Postolache[31], Leonard Sandin[11] and Piet Verdonschot[6]

Partners 16 (CNR-IRSA, Italy), 4 (UDE, Germany), 3 (NERC, United Kingdom), 6 (ALTERRA, The Netherlands), 15 (BOKU, Austria), 26 (MasUniv, Czech Republic), 11 (SLU, Sweden), and 31 (UNIBUC-ECO, Romania)

A project under the 6th Framework Programme
Sustainable development, global change and ecosystems

INDEX

ANNEXES

ANNEX 1: WP 2, Task 1.1 catchment data questionnaire
ANNEX 2: WP 2, Task 1.1 hydromorphological features document
ANNEX 3: Task 1.1 Partners details and e-mail addresses

WP2 : CLIMATE –HYDROMORPHOLOGY INTERACTIONS
Task 1: Effects of climate/land use changes on hydro(morpho)logy
Subtask 1.1 Rivers : Environmental data collection and analyses

Task Leader: Andrea Buffagni (CNR), buffagni@irsa.rm.cnr.it
Partners: ALTERRA, BOKU, NERC, CNR, MasUniv, SLU, UDE, UNIBUC-ECO
Period: month 1-9

CLIMATE-HYDROMORPHOLOGY INTERACTIONS THROUGH CHANGES IN LAND-USE AND DISCHARGE: REVIEW OF INFORMATION RELATING SELECTED STUDY CATCHMENTS ACROSS EUROPE

1 INTRODUCTION

1.1 WP2, Task 1.1: principle aim

Within Euro-limpacs, the aim of WP 2, Task 1.1, is to give an overview of the interactions between climate, hydrology, land-use and morphology under past and present conditions for selected river catchments throughout Europe. Collected data from the selected catchments will be used to draw general conclusions on the following research questions:

- What is the relation between climate change/land-use – hydrology (discharge) – hydromorphology?
- What is the effect of the intensification/withdrawal of land – use from the floodplain on hydrology and hydromorphology?

In particular, the effects of two different potential changes in land-use following climate change has to be predicted on the basis of scenarios for future river morphology that cover amongst others the extent of buffer strips, the development of riparian vegetation, the supply of coarse woody debris and the potential for channel form restoration.

1.2 WP2, Task 1.1: workplan and related activities

As indicated in the detailed workplan, each partner (Task 1.1 contact persons and e-mail addresses in Annex 3) started a collection of hystorical and present existing data on his own catchment, because the respective partner is the one who knows the catchment best and the methods for field work and data analyses should be directly related to each catchment specific stressors and indicators.

Detailed workplan – Activities (with participants listed)

Month(s)	Activity No.	Description of activity	Partners Involved
1-	1	Collection of historical and present existing data	CNR-IRSA, ALTERRA, BOKU, NERC, MasUniv, SLU, UDE, UNIBUC-ECO
1-	2	Collaborate with CCT Climate scenario	UNIBUC-ECO
1-	3	Collaborate with CCT Space for time	CNRS-UPS, (CNR-IRSA)
1-	4	Collaborate with CCT Metadatabase	NERC
1-	5	Collaborate with WP 1	UNIBUC-ECO
2	6	Questionnaire on final study catchments selection and data availability sent to partners	CNR-IRSA, (NERC)
3	7	Answering questionnaire	All WP2 partners
6-9	8	Analysis of relations (multivariate, regression, etc.)	CNR-IRSA, ALTERRA, BOKU, NERC, MasUniv, SLU, UDE, UNIBUC-ECO
6	9	Participating in CCT Space for time workshop	CNR-IRSA, CNRS-UPS,
9	10	Report writing	CNR-IRSA, ALTERRA
9	11	Submitting report	CNR-IRSA
9-12	12	Checking/Formatting Land-use – hydromorphology data and send to WP6	All with suitable data

Adequate data sets are fundamental to establish the interrelation of land use patterns, floodplain use and hydromorphological condition. To evaluate data availability in the selected study catchments, during the meeting held in Innsbruck, on March 2004, a preliminar list (inserted in WP2 year 1 workplan) of data availability has been filled in by Task 1.1 partners. In June 2004, as indicated in Task 1.1 detailed workplan, CNR-IRSA compiled and sent to each WP 2, Task 1.1 partner a "Questionnaire on final study catchments selection and data availability" (Annex 1) with the aim to update and complete the list of data availability. During the meeting held in Wageningen, 22-24 November, CNR-IRSA presented a 30-pages report on partners questionnaire answers.
The circulation of the information collected should help partners:

- to get a clearer idea of which kind of data/analysis each partner intended to collect/perform;
- to select which data to collect, if still to be decided in details, to make things around Europe more comparable.

According to this objective, a list of hydromorphological features (Annex 2) and of hydromorphological surveys methods adopted by Task 1.1 partners has been compiled and circulated among Task 1.1 partners.
More comparable data and consequently more comparable results within WP2 Task 1.1 are a very important goal because this Task:

- will provide an overview of the interactions between climate, hydrology, land-use and morphology under past and current conditions throughout Europe and will be used to set up a more general framework for Cause-Effect-Chains on the interaction of climate and hydromorphology through changes in land-use and discharge.
- will form the basis for subsequent tasks and the collected data will directly support activities in WP6.

1.3 Notes on final report writing and deadlines

The catchments general descriptions delivery date (end of December 2004) has been respected by all partners. On the contrary the deadline for sending results has created some problems. Not all partners has respected the fixed deadline of the 15th of January 2005, consequently some contributions inserted in the first version of the report are lacking of data analysis and results; in this final version only one partner contribution is still incomplete and, according to partner intent, it will be available in the next months.

1.4 Questionnaire collected data

To picture the current situation within Euro-Limpacs, WP2, Task 1.1 emerging from partners'responses, the questionnaire collected data are here reported. Within each argument the different answers have been merged to evidence the common general tendencies and the existing differences.

A. Climatic/discharge/land use scenarios (Table 1)

Climatic/discharge

Except for MasUniv, which uses a time horizon referred to 2050, all partners time horizons are referred to 2070-2100.

The common tendencies evidenced by the local climatic alteration scenarios expected are a general increase in temperature, with summer warming peaks which should reach locally 7°-10°C in South Europe (as evidenced by CNR). The annual precipitations should slightly decrease and, as expected, the warming will be accompanied by reduced snow cover. In particular the precipitations should decrease in summer (August, September) and increase in winter or in October. Extreme daily precipitation should increase, specially in summer, with an increase of summer storms.

Consequently, discharge will show a more dynamic regime due to increases in extreme daily precipitation, a change in the timing of flows (due to reduced snow cover), with a shift from a winter minimum to a late summer minimum, and an increase in severity of droughts and in extreme floods.

Land use

Land use scenarios differ between different partners: they depend on the current land use within each study catchment and are closely connected with hydrological scenarios. As evidenced by ALTERRA and CNR, a common tendency should concern the increase of urbanisation which will slightly increase flood risk in the next years.

Moreover, as highlighted by BOKU and NERC, higher temperatures may lead to changes in:

- ✓ the extent of riparian wetland in the catchment;
- ✓ species composition of the forest (e.g. coniferous trees will be replaced by deciduous trees);
- ✓ nutrient resource;
- ✓ sediment input rates and dynamics;

In riparian zone, both an extension/restoration of buffer zone of river predominantly replacing cropland areas both habitat modification and losses are expected.

As consequence, the effects on hydromorphology of two potential changes in land-use following climate changes could be:

- ✓ less intensive precipitation, higher temperatures and more intense floods could remove agricultural land use (predominantly cropland areas) from riparian zone and lead to a extension/restoration of buffer zone of rivers.
- ✓ more intensive precipitation, lower temperatures may lead to more extensive agricultural land use and reforestation.

Partner	Current land use and trend	Land use scenarios	Precipitation scenarios	Discharge scenarios
ALTERRA	In the floodplain changes from grassland to fields.	-agricultural land + urbanisation	+ winter precipitation + summer storms.	+ dynamic regime + summer extreme floods.
BOKU				+ dynamic regime.
CNR	Main current land uses: forest cover, agricultural land, grassland.	+ urbanisation riparian zone: - agricultural land (maize) + forest cover	- total precipitations and snow; + extreme daily precipitations.	+ dynamic regime; change timing of flows.
MasUniv		riparian zone: + buffer zone -cropland areas	- total precip: - in Summer + in October.	+ extreme floods; Summer-Autumn droughts.
NERC	+ tillage - grazed pasture and semi-natural meadow.	+ tillage - grazed pasture; Alternative: - tillage + grazed pasture;	Not yet delineated.	Not yet delineated.
SLU		Not yet delineated.	-10-40% annual runoff; -summer runoff; -number high flows.	Change in timing of flows.
UDE		- agricultural use close to the river.		
UNIBUC-ECO	Reduction of wetland zones and more land used for agriculture.	+ agriculture - wetland zones; Alternative: + wetland zones.		- discharge + flows

Table 1: summarized information on current land use, its observed trends, climatic, discharge and land use alteration scenarios expected by different partners. + means an increase, - means a decrease.

Bibliographic references

Climatic/discharge scenarios

Andreasson J., S. Bergstrom, B. Carlsson, L.P. Graham & G. Lindstrom, 2004. Hydrological change – climatic change impact simulations for Sweden. Ambio 33 (3-4): 228-234.

Arnell N.W., 1999. The effect of climate on hydrological regimes in Europe: a continental perspective. *Global Environmental Change*, 9: 5-23.

Hladny J. et al. (1997). Impacts of a Potential Climate Change on Hydrology and Water Resources in the Czech Republic. Praha 1997. 135 p.

Kalvova J. et al. (1996). Climate Change Scenarios for the Czech Republic. Praha 1996. 101 p.

Nitrogen **Co**ntrol by **La**ndscape **S**tructures in Agricultural Environments – (NICOLAS) - EVVA-CT97-0395 and **E**uropean **V**aluation and **A**ssessment too**L**s s**U**pporting **W**etland **E**cosystem legisla**T**ion (EVALUWET) – EVK1 - CT - 2000 - 00070.

Räisänen J., U. Hansson, A. Ullerstig, R. Döscher, L. P. Graham, C. Jones, M. Meier, P. Samuelsson & U. Willén, 2003. *GCM driven simulations of recent and future climate with the Rossby Centre coupled atmosphere – Baltic Sea regional climate model RCAO*. SWECLIM programme and EU PRUDENCE project, report number: RMK No. 101, January 2003, 61 pp.

van Walsum P.E.V., P.F.M. Verdonschot & J. Runhaar (eds.) 2002. Effects of climate and land-use change on lowland stream ecosystems. Alterra-report 523, ISSN 1566-7197. 200 pp.

Land use scenarios

There are no bibliographic references for the study catchments: land use scenarios have been generated applying general concepts to the current land use.

B. Collected data

Land and floodplain use, hydromorphological and soil type data

Tables with information on land and floodplain use (Table 2), hydromorphology (Table 3) and soil type data (Table 4) here reported are the tables compiled at Innsbruck, with available updates. The most common data source available is GIS, with a spatial resolution of 1:50000. Globally data are referred to 1995-2000 situation.

Land and floodplain use				
Catchment	**Name of data source**	**Spatial resolution**	**Parameter types covered**	**Temporal resolution**
lowlands				
River Becva	CORINE		Land cover	
River Vechte	GIS	1:50000		
River Lambourn	Intelligent River network (GIS).	1:50000	Altitude of site/source, slope, distance to source/mouth, stream order, solid geology, drift geology, catchment area.	Time invariant data.
River Lambourn	Land Cover Map	25 m resolution	25 land use classes	1999, 2000.
River Neajlov	CORINE	1:100000	Land use.	1995.
mountains				
River Waldaist	GIS (Doris)	1:50000		
River Eder	CORINE/GIS ATKIS	1Km segment, 100-1000m straps along the river; 1:5000 possible;		
River Orco	GIS	1:100000	Altitude of site/source, slope, distance to source/mouth, geology, catchment area.	2000.

Table 2: selected study catchments land and floodplain use existing data.

Hydromorphological data here reported have been collected in the following catchments (Table 3) according to different survey methods with a spatial resolution ranging from 100 to 500 metres and referred to 1993 till present situation.

Hydromorphology				
Catchment	**Name of data source**	**Spatial resolution**	**Parameter types covered**	**Temporal resolution**
lowlands				
River Lambourn	River Habitat Survey	A 500 stretch within every 1 km of the river.	15 groups of variables.	2003 survey and earlier surveys with less comprehensive catchment coverage.
River Neajlov	Digital Elevation Model	100 m	Derived parameters slope, flood direction, exposition etc.	1993
mountains				
River Waldaist	Ökomorphologische Zustandtskartierung			
River Eder	Gewässerstruktur-gütekartierung	100 m stretches.	29 hydromorphological parameters.	1 record from 2000.
River Orco	River Habitat Survey SE	A 500 stretch.	15 groups of variables.	2004-2005 survey.
River Chiusella	River Habitat Survey SE	A 500 stretch.	15 groups of variables.	2004-2005 survey.

Table 3: selected study catchments existing hydromorphological data.

Soil type data available (Table 4) are referred to a spatial scale ranging from 1 Km^2 to 1:200000, mostly time invariant.

Soil type				
Catchment	**Name of data source**	**Spatial resolution**	**Parameter types covered**	**Temporal resolution**
lowlands				
River Lambourn	National Soil Resources Institute.	1 Km^2 resolution	NATMAP vector.	Time invariant data.
River Neajlov	National Soil distribution map.	1:200000	Soil types distribution.	
mountains				
River Waldaist	Diploma thesis Soil analyses.			
River Orco	GIS	1:100000		Time invariant data (2000).

Table 4: selected study catchments soil type data

Discharge data

With catchment data questionnaire, detailed information on hystorical and present existing discharge data for the study catchments, in particular, on the number and position of gauguing stations, on data record frequencies and on time series availability has been collected (Table 5).

In the selected model catchment are present 1 to 15 gauguing sites which are almost distributed throughout the catchments, from headwater to the mouth of the catchment, often near the confluence of tributaries. Usually the discharge data are available as monthly averages measurements, sometimes daily and hourly discharges are available too, with a time series ranging from 10 to 100 years, mostly 20-40 years.

Catchment	Number of gauging sites	Position of gauging sites	Data record frequencies	Time series available
lowlands				
River Becva	5	From mouth to upper course.	Daily or monthly averages; last decade hourly.	Since 1920 and 1961.
River Vechte	7 (6)	From mouth to upper course.	Daily averages.	since 1970-1980; the longest from 1950 (1900?) until now.
River Dinkel	2	Spread out in the catchment.	Daily, aggregated to monthly averages.	Generally at least 10 years.
River Emån	16	Spread out in the catchment.	Continuous.	-
River Lambourn	4	From mouth to upper course.	Daily averages.	Since 1962 till present; 1962-1983; 1966-1983.
River Neajlov	7	4 on tributaries and 3 from the upper part to confluences.	Daily and monthly.	20 years.
mountains				
River Waldaist	2 (3)	1 in middle reach, 2 in lower reach.	Daily.	1 station with discharge since 1984, 2 stations since 1976.
River Lahn	2	Spread out in the catchment.	Daily, aggregated to monthly averages.	Generally at least 10 years.
River Eder	4	Spread out in the catchment.	Daily, aggregated to monthly averages.	Generally at least 10 years.
River Orco	1	Middle reach.	Discontinuous.	No.
River Chiusella	1	Middle reach.	Discontinuous.	No.

Table 5: Summary of information on study catchments discharge data.

Rain and other climatic data

Information collected within each study catchment on the number of stations of climatic data record, data typology, record frequencies and time series availability is reported in Table 6.

Catchment	Rain data type	Number of rain stations	Data record frequencies	Time series available	Other climatic data
lowland					
River Becva	Precipitation.	4-5 relevant stations.	Daily amount.	30 years.	Air temperature sunshine duration.
River Vechte	Precipitation number of precipitation days, extreme amount per 0.1 hour.	From 1 to 4 relevant stations.	Daily amount (mm).	from 70 to ? years.	Air temperature sun hours, evaporation.
River Dinkel	Precipitation.	1	Daily/monthly amount.	?	Air temperature.
River Emån	Precipitation number of precipitation days, extreme daily precipitation snow cover.	Around 20.	Usually every 6 or 12 hours.	More than 20 years.	Air temperature.
River Lambourn	Precipitation.	7 relevant stations.	Hourly and daily measurements.	From 70 to 4 years.	Max and min air temperature soil temperature wind direction and speed, sunshine amount.
River Neajlov	Rain; number of precipitation days; extreme daily precipitation; snow cover.	1 (2?)	Daily amount.	10 years.	Solar radiation, air Tmed, Tmin Tmax and soil Tmed, Tmin, Tmax.
mountain					
River Waldaist	Precipitation.	3	Daily data.	10 years.	Diurnal air temperature range, Tmin, Tmax.
River Orco	Precipitation, monthly number of precipitation days, extreme monthly precipitation, snow cover.	2	Daily data.	Data since 1993.	Air temperature.
River Chiusella	Precipitation, monthly number of precipitation days, extreme monthly precipitation; snow cover.	1	Daily data.	Data since 1996.	Air temperature.

Catchment	Rain data type	Number of rain stations	Data record frequencies	Time series available	Other climatic data
River Lahn	Precipitation.	1	Daily/monthly amount.	?	Air temperature.
River Eder	Precipitation.	1	Daily/monthly amount.	?	Air temperature.

Table 6: Summarized information on hystorical and present day existing rain and other climatic data in the study catchments.

Within each study catchment, daily precipitation amount data are recorded from at least 1 to 20 stations and with a time series ranging from 4 to 70 years. In many cases the number of precipitation days, extreme daily precipitation and the snow cover are available too. Among other climatic data, air temperature is available for all the selected study catchments.

C. Data analisys

When the questionaire circulated most partners had not yet decided the data analysis technique to use. The summarized information on data analysis methods and on hydromorphological models experience (Table 7) give a general overviev on the approaches each partner planned to adopt in the study of the relationships between climate-land use-hydrology-hydromorphology.

Partner	Data analysis method	Hydro-morphological models	
		Model name	Spatial scale
ALTERRA	Trend analysis.	Hydrological models: SIMGRO and SWAT; Morphological models: no.	Sub catchment scale.
BOKU	Multivariate analysis (?).	Never used any.	-
CNR	Regression, pattern and multivariate analysis.	Never used any; Intend to develop a model to relate meso/microhabitat distribution-landuse-climate interactions;	River reach (500 metres).
MasUniv	Time series analysis, multivariate analysis.	Never used any.	-
NERC	Multivariate ordination and regression techniques.	Never used any.	-
SLU	Not yet decided.	Never used any.	
UDE	Bivariate (e.g., Pearson / Spearman) and multivarite statistics (e.g., Multiple Linear Regression, MANOVA).	-	-
UNIBUC-ECO	Regression, pattern and multivariate analysis.	Hydromorphological model: SWAT; DIFGA and MONERIS.	Catchment scale; We have used the model to evaluate the erosion process at the catchment scale.

Table 7: Data analysis methods preliminar indications and hydromorphological models existing experience.

Most part of partners indicated multivariate ordination and regression techniques as selected data analysis methods to study the relationships between land use and hydromorphology. Trend analysis and bivariate statistics were also indicated as possible usefull methods.

As indicated by CNR and NERC, the relationships between land use and hydromorphology could be analysed trying to relate the River Habitat Survey HQA, HMS, LRD score for a 500m site and the occurrence of its component variables to the catchment land use and hydrological regime using multivariate ordination and regression techniques. In particular the River Habitat Survey South European version (RHS SE) method could be used to relate micro/mesohabitat occurrence with hydromorphological and land use data.

The answers to the proposed questions on hydromorphological models evidenced as only two partners (ALTERRA and UNIBUC-ECO) have experienced the use of models. The hydro-morphological models used were SWAT, SIMGRO, DIFGA and MONERIS. SIMGRO and DIFGA are hydrological assessment tools, SWAT (Soil and Water Assessment Tool) model was developed to simulate varying hydro-physical processes including water, sediment and agricultural chemical yields in large complex watersheds and MONERIS has been used to study nutrient emissions. The models have been used at catchment and sub-catchment spatial scale. This spatial scale could be appropriate to infer on habitat availability and discharge pattern changes following land use and climate variations but, up to now, general models, simple to use, are not available and every model can only be used in the areas it was set up for. Nevertheless it could be interesting to use hydromorphological models to study erosional/depositional phenomena in rivers.

CNR intend to develop a simple predictive model at a spatial scale of river reach (500 metres) to relate climate- land use- hydromorphology- meso/microhabitat distribution. The model will be based on RHS South European version data: HQA, HMS, LRD score and the occurrence of the recorded hydromorphological features will be related to meso/microhabitat distribution, discharge/rain and land use data. it could be interesting to use hydromorphological models to study morphological modifications resulting, for example, from erosional/depositional phenomena in rivers;

D.Cause Effect Chain and Cause Effect Recovery chain (Table 8)

To the question on which hypothetical Cause Effect Chain (CEC) will better reflect the interactions between climate change and river hydromorphology through land use/discharge alterations in each model catchment:

1. hydromorphological deterioration through intensification of land-use or through a more variable discharge regime that results in habitat modification and losses;
2. a significant improvement of hydromorphology for the withdrawn of human disturbances from the floodplain due to more frequent flood events or as a result of floods that generate a near-natural habitat structure;

WP 2, Task 1.1 partners answered underlining the following arguments.

ALTERRA, UDE and MasUniv are expecting for the future a hydromorphological improvement; on the contrary BOKU and UNIBUC-ECO evidenced as in their study catchments a hydromorphological deterioration is expected and, finally, other partners underline as both the CEC shall be expected .

The partners answer on restoration measures which might be usefull in improving channel morphology (Cause Effect Recovery chain) evidence as the existing and future experience on the selected study catchments concerns the following categories of restoration measures:

-morphological;
-water quality;
-biological;

The morphological restoration measures evidenced are the re-meandering, the positioning of sand traps, the reduction of intervection, the removal of instream structures and the introduction of fallen trees into the channel. The water quality and the biological restoration measures indicated are the construction of buffer zones and trout fisheries habitat management practice.

Differences in proposed measures underline as the success of restoration measures depends on steering the appropriate key factors, which differ from stream to stream and site to site (Verdonschot & Nijboer, 2002).

Partner	Catchment	CEC expected	Recovery measures
ALTERRA	River Vechte	2 Hydromorphological improvement.	M: Remeandering W: Buffer strips
BOKU	River Waldaist	1 Hydromorphological deterioration.	M: Sand traps
CNR	Orco, Chiusella rivers	1 Hydromorphological deterioration; 2 H. improvement.	M: Reduction of intervenction W: buffer strips
MasUniv	River Becva;	2 Hydromorphological improvement.	-
NERC	River Lambourn	1 Hyrmorphological deterioration; 2 H. improvement.	M: Reduction of intervenction B: trout fisheries habitat management practice
SLU	River Emån	-	-
UDE	River Lahn	2 Hydromorphological improvement.	M: Introduction of fallen trees and removal of instream structures W: buffer strips
UDE	River Dinkel		M: Introduction of fallen trees and removal of instream structures W: buffer strips
UDE	River Eder	2 Hydromorphological improvement.	M: Introduction of fallen trees and removal of instream structures W: buffer strips
UNIBUC-ECO	River Neajlov	1 Hydromorphological deterioration.	W: Buffer strips

Table 8: Summarized information on CEC expected and recovery measures. M = Morphological measures; W = Water quality measures; B = Biological measures.

Cause Effect Chain and Cause Effect Recovery chain bibliographic references

Beechie T. & S. Bolton, 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest Watersheds. Fisheries (24), 6-15.

Bisson P. A., S. M. Wondzell, G. H.Reeves & S. V. Gregory, 2003. Trends in using wood to restore aquatic habitats and fish communities in western North American rivers. in: S. Gregory, K. L. Boyer and A. M. Gurnell. The ecology and management of wood in world rivers. American Fisheries Society, Symposium 37, Bethesda, Maryland, 391-406.

Driessen J.M.C., P.F.M. Verdonschot & J.A. Schot, 1998. Stream rehabilitation in The Netherlands: present status and future developments. In: H.O. Hansen & B.L. Madsen, River Restoration '96, Session lectures proceedings. International Conference arranged by the European Centre for River Restoration: 254-260. National Environmental Research Institute, Denmark".

Frissell C. A. & R. K. Nawa, 1992. Incidence and causes of physical failure of artificial habitat structures in streams of Western Oregon and Washington. North American Journal of Fisheries Management (12), 182-197.

Kail J., 2003. Influence of large woody debris on the morphology of six central European streams. Geomorphology (51), 207-223.

Kauffman J. B., R. L. Beschta, N. Otting, & D. Lytjen, 1997. An ecological perspective of riparian and stream restoration in the Western United States. Fisheries (22), 12-24.

Kondolf G. M. 2000. Some suggested guidelines for geomorphic aspects of anadromous salmonid habitat restoration proposals. Restoration Ecology (8), 48-56.

Roni P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock & G. R. Pess, 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management (22), 1-20.

Roper B. B., D.Konnoff, D. Heller & K. Wieman, 1998. Durability of Pacific Northwest instream structures following floods. North American Journal of Fisheries Management (18), 686-693.

Wright J.F., R.T. Clarke, R.J.M. Gunn, J.M. Winder, N.T. Kneebone, & J. Davy-Bowker, 2003. Response of the flora and macroinvertebrate fauna of a chalk stream site to changes in management. Freshwater Biology, 48, 894-911.

Wright J.F., R.T. Clarke, R.J.M. Gunn, N.T. Kneebone, & J. Davy-Bowker, (in press). Impact of major changes in flow regime on the macroinvertebrate assemblages of four chalk stream sites, 1997-2001. River Research and Applications.

1.5 Short review on simulated climatic scenarios (2071-2100) and hydrological behaviour (2050s) across Europe

1.5.1 Introduction

In Euro-Limpacs, the aim of WP 2, Task 1, is to predict the effects on hydromorphology of two different potential changes in land-use following climate change. The first step to reach this purpose is the collation of recent existing data on climate change simulations. As contribution to the European PRUDENCE Project, the Rossby Centre, part of SMHI and the Swedish Regional Climate Modelling Programme SWECLIM, has published the report RMK No. 101, on January 2003, reporting a set of regional climate change simulations representing the climate in the late 21 st century (2071-2100). Data furnished in this report have been extracted from this report. Regional climate models permit to derive climate change scenarios on spatial scales that are currently not amenable by general circulation models. They can provide input data for climate impact studies: the improved representation of severe weather phenomena has stimulated their applications concerned with the variability, change and impact of extreme events, especially those of heavy precipitation and drought (Frei et al., 2003).

The second step is the collation of data on the simulated effects of climatic change on European hydrological behaviour. Most of the work related to this step was funded by the European Commission too, in particular, the data furnished in this report have been extracted from an investigation (Arnell, 1999) on the effects of climate change on European water resources (EV5V-CT93-0293).

1.5.2 Climatic scenarios

For portraying the climatic results is used the general subdivision from northern (Sweden, the Baltic Sea runoff area, the Baltic Sea) and southern (south of 49°N) Europe (Figure 1).

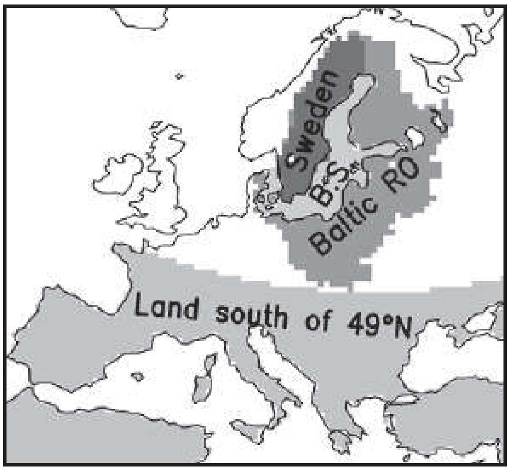


***Figure 1**. The RCAO model domain. The general subdivision from north (Sweden, the Baltic Sea runoff area the Baltic Sea) and south Europe (land south of 49°N) is shown* (from Räisänen et al., 2003).

Surface air temperature

A general time-averaged warming is produced in all scenarios (Figure 2), with the maximum annual mean warming occurring in central and southern Europe.

In northern Europe, the warming is largest in autumn and winter

In southern and central Europe, the warming peaks in summer, with a maximum of over 7-10°C in France. This very large warming is accompanied by substantially reduced cloudiness, precipitation and soil moisture.

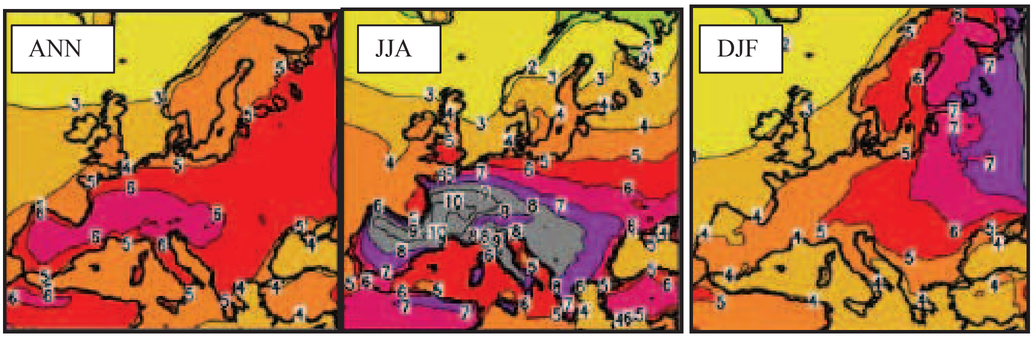


***Figure 2**. Changes in seasonal (JJA = Summer, DJF = winter) and annual (ANN) mean surface air temperature (differences from the corresponding control run 30-year means) in the RCAO climate change simulations. Contours and shading at every 1°C* (from Räisänen et al., 2003).

Interannual variability of monthly mean temperatures

- A decrease in interannual temperature variability in northern Europe in winter is produced. A tendency towards reduced mid- and high-latitude temperature variability in winter in a warmer climate also occurs in global climate models, most likely due to a reduction of snow and ice (Räisänen 2002).
- In summer, variability changes little in northern Europe but tends to increase further south. A slight increase in midlatitude temperature variability in summer is likewise a common model result, which probably reflects reduced soil moisture. When the soil becomes sufficiently dry, the capability of evaporation to cool the surface decreases. This acts to increase both the average summer temperatures and their interannual variability, because the lack of evaporative cooling has its largest effect in those summers when the atmospheric circulation favours warm conditions and, with sufficient soil moisture, large evaporation (Delworth & Manabe 1988, 1989; Tett et al.1997).

Diurnal temperature range

- In northern Europe, the annual mean diurnal range decreases, locally by over 25%, with the largest decrease in variability from late autumn to spring. The decrease in snow cover, which prevents temperature from falling to very low levels in clear nights, is a main suspect for this.
- Further south the diurnal temperature range increases slightly in most of the year, with the largest relative increase in those parts of southwestern Europe (in particular France) where the decrease in cloudiness is largest.

Temperature extremes

Tmax

- In northern Europe, the increase in yearly maximum temperatures is broadly the same as that in the June-July-August mean temperature
- In south Europe, the warm extremes generally increase more than the mean temperature, even though the summer time mean warming is also very large. In France, the highest yearly maximum temperatures increase by up to 12°C. This is consistent with the increased interannual and diurnal temperature variability discussed in the previous subsections.

Tmin

- The lowest winter minimum temperatures increase in most of Europe much more than the December-February mean temperature.
- The largest changes occur in southern Scandinavia and central-eastern Europe, where the increase exceeds 15°C, corresponding to areas which become almost snow-free in the scenario runs.
- In southwestern Europe, the change in the lowest winter temperatures is more modest. Even in northern Scandinavia, where a good deal of snow remains even in the scenario runs, the changes in the lowest minimum temperatures tend to be somewhat smaller than those in eastern and central Europe.

Precipitation

Time mean precipitation (figure 3)

A general increase in precipitation in northern and central Europe in winter is simulated by all scenarios. They also agree on a general and in some areas very large (up to 70% in the A2 scenario runs) decrease in summer precipitation in southern and central Europe. A smaller decrease in summer precipitation extends up to central Scandinavia in the north. Thus, the changes in northern and central Europe have a very pronounced seasonal cycle.

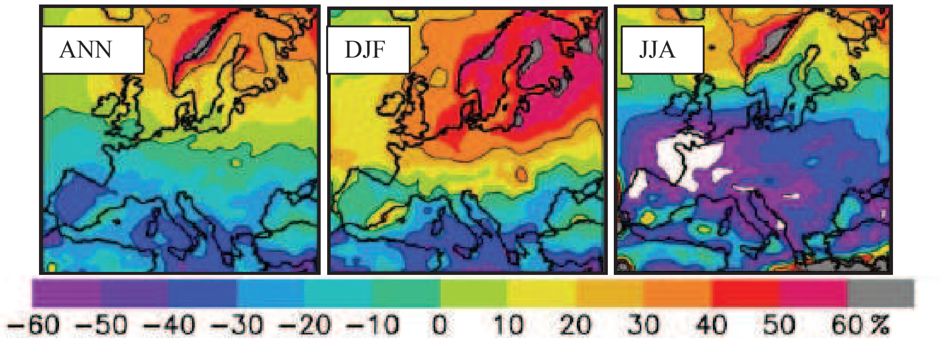


Figure 3. *Changes in seasonal and annual mean precipitation (per cent differences from the corresponding control run 30-year means) in the RCAO climate change simulations. The colour scale is given below the figure. Contours are drawn at every 30%.*

Interannual variability of monthly precipitation

- the general picture is one of increasing standard deviation in northern Europe
- decreasing standard deviation in southern Europe.

Number of precipitation days

- in northern Europe the number of very wet days increase
- in the area south of 49°N, the total number of precipitation days decreases substantially.

Extreme daily precipitation

An overall (north and south Europe) increase in the yearly extremes, even in those parts of southern and central Europe where the mean annual precipitation decreases.

Snow conditions

- a substantial shortening of the snow Season, with the largest changes (from 45 to over 90 days) occur from central Scandinavia to the Baltic states, at the west coast of Norway and over the Alps. These areas have a comparably decent snow season in the control runs but are_milder and therefore more sensitive to temperature increase than northern Scandinavia,_where the decrease in snow season length is smaller.
- In areas like southernmost Scandinavia and central Europe the decrease in the snow season length is also smaller in absolute terms but large in relative terms. For example, those parts of southwestern Sweden that have 30-60 snow_days become almost snow-free (less than 10 snow-covered days).

Other aspects of the surface hydrology

Evaporation

- The simulated annual mean evaporation increases in northern Europe and most of central Europe (about 20%) in all seasons, however, the increase is in relative terms largest in winter and spring.
- In much of southern Europe, the simulated decreases in precipitation also lead to a decrease in annual evaporation. Evaporation generally increases in this area in winter and early spring, but decreases in summer and autumn because of a marked decrease in soil moisture, leaving more radiation energy to drive the sensible heat flux, contributing in this way to the large increase in summer temperatures.

Runoff generation

- In most of northern Europe, the annual runoff generation increases.
- In central and southern Europe annual runoff generation decreases.

The runoff is affected by changes in snow conditions and soil moisture, as well as precipitation and evaporation:

- in North Europe, the earlier snowmelt gives an earlier spring peak in runoff generation. Increased precipitation and snowmelt during the late autumn and winter leads to a substantial increase in runoff generation in these seasons. Conversely, the earlier snowmelt together with reduced summer precipitation and increased evaporation leads to a decrease in runoff generation in summer.
- in south of 49°N, the area mean runoff generation decreases almost throughout the year, at least excluding the midwinter and early spring.

Soil moisture

Mean annual soil moisture decreases in most of Europe, with the main exception being northern Scandinavia and Russia. The decrease is largest in central and southwestern Europe. Further south, the decrease in soil moisture is limited by the fact that the soil is very dry even in the control simulations.

Average seasonal cycles of soil moisture:

- In north Europe little change occurs in winter, when the soil is very wet in all the simulations. However, the seasonal decrease in soil moisture toward late summer is larger in the scenario runs due to the earlier snowmelt, increased evaporation and reduced summer precipitation.
- In south Europe the area mean soil moisture is reduced throughout the year, but the most remarkable feature is the extreme dryness of the soil in late summer.

1.5.3 Hydrological results

The Effects of climate change on European hydrological behaviour are referred to the 2050s, and distinguish maritime (south-west), eastern and continental (north-east) parts of Europe.

Change in the annual water balance

For average annual runoff:

- large reductions across all south Europe (south 50°N)
- increases in north Europe.

Changes in seasonal flow regimes

The change in the month of maximum runoff:

- little change in the maritime parts of Europe
- more substantial changes around the margins of the areas with snow affected regimes (es. Poland), where the month of maximum flows moves forwards one month (as the snowmelt season occurs earlier).

The change in the month of minimum runoff:

occurs where snow cover is substantially reduced or eliminated. In these regions shift from a winter minimum (es Alps) to a late summer minimum.

- In general the timing of flows does not vary in the maritime parts of Europe or in cold regions (es. Russia) but change in the marginal snow-affected areas (es.southern Sweden and southern Finland).

Changes in low flows and droughts

- Low flows (Q90) increase in eastern and upland Europe, because of the change of the amount of snowfall and snowmelt (during the minimum flow season –winter- precipitation fall as rain).
- In the maritime parts of Europe low flows decrease over large areas (follow the change in summer runoff, with a larger area than that showing a reduction in annual runoff).

The intensity of drought:

- increase across western Europe
- decrease in eastern and northern Europe.

Changes in inter-annual variability in runoff

A general tendency towards an increase in relative variability of between 5 and 10 %.

1.5.4 Conclusions

Climatic data (Table 1)

In conclusion, the dramatic summertime warming and drying in central and southern Europe, combined with the increase of extreme events might have serious consequences on rivers hydromorphology. It is therefore important to integrate different knowledge (hydrological, hydromorphological, substrate/habitat stability, biological, climatic data) for the assessmemt and management of climatic changes impacts on freshwater ecosistems.

Variable	Season	North Europe	South Europe
Air temperature	Annual	+	++
	Autumn-Winter	+	
	Summer		++ (7-10°C)
Interann. variab. of monthly mean temp.	Winter	–	
	Summer		+
Diurnal temperature range	Annual	– (–25%)	+
	Autumn to spring	–	
T max	Annual	= *	++ (+12°C)
T min	Winter	+	+
Precipitation	Winter	+	
	Summer		–
Interann. variab. of monthly precip.	Annual	+	–
Num.of precip. days	Annual	+	–
Extr.daily precip.	Annual	+	+
Snow cover	Annual	Shorter	Shorter
Evaporation	Annual	+ (+20%)	–
	Winter-spring	++	–
	Summer-Autumn		+
Runoff	Annual	+	–
	Autumn-Winter	+	
	Spring peak	Earlier	
	Summer	–	=
	Mid wint-early spring		
Soil moisture	Annual	–	–
	Winter	=	–
	Late summer	–	––

Table 1. General results of climatic simulated scenarios (2071-2100) in north and south Europe. + is referred to an increase, ++ to a larger increase, – to a decrease, ––to a larger decrease from the control simulation. =* means no difference from the mean increase of T value in summer, = means no variation.

Hydrological behaviour simulations (Table 2)

Variable	Season	maritime Europe	eastern Europe	continental Europe
Timing of flows	Spring flow		-	
	Winter runoff	+	+	+
	Summer runoff	-		-
Low flows	Annual	-		+
Variab. in ann. river flows	Annual	+	+	+

Table 2. General results of hydrological simulated scenarios (2050s) in maritime, eastern and continental Europe. + is referred to an increase, – to a decrease.

1.5.5 References

Arnell N.W., 1999. The effect of climate on hydrological regimes in Europe: a continental perspective. *Global Environmental Change*, 9: 5-23.

Delworth T. L. & S. Manabe, 1988. The influence of potential evaporation on the variabilities of simulated soil wetness and climate. *Journal of Climate*, 1: 523-546.

Frei C., J. Hesselbjerg Christenses, M. Dequé, D. Jacob, R. G. Jones & P. L. Vidale, 2003. Daily precipitation statistics in regional climate models: evaluation and intercomparison for the European Alps. *Journal of Geophisical research*, 108 (D3), 4124, doi:10.1029/2002JD002287.

Räisänen J., 2002. CO2-induced changes in interannual temperature and precipitation variability in 19 CMIP2 experiments. *Journal of Climate*, 15: 2395-2411.

Räisänen J., U. Hansson, A. Ullerstig, R. Döscher, L. P. Graham, C. Jones, M. Meier, P. Samuelsson & U.Willén, 2003. *GCM driven simulations of recent and future climate with the Rossby Centre coupled atmosphere – Baltic Sea regional climate model RCAO*. SWECLIM programme and EU PRUDENCE project, report number: RMK No. 101, January 2003, 61 pp.

Tett S. F. B., T. C. Johns & J. F. B. Mitchell, 1997. Global and regional variability in a coupled AOGCM. *Climate Dynamics*, 13: 303-323.

1.6 Climate-hydromorphology interactions

In large parts of Europe hydromorphological alterations as channel straightening, dam construction, disconnection of the river from its floodplain and alteration of riparian vegetation are the main stressors affecting rivers. Under predicted future climate scenarios further stresses will be introduced including the combined effect of changes in precipitation, temperature and climate induced changes in land-use patterns. These in turn may cause changes in catchment hydrology that will affect sediment transport and channel morphology, inundation frequency and extent, and impact aquatic ecosystems at both catchment and habitat scale. For each catchment the actual hydromorphological condition and land-use will be linked to identifye two alterantive land-use scenarios and to evaluate cause-effect relationships under climate and global changes scenarios. The alternative key hypotheses are:

- ✓ global change may cause hydromorphological deterioration through intensificatioin of land-use or through a more variable discharge regime that results in habitat modification and losses;
- ✓ alternatively, global change may cause significant improvement if, for example, human disturbance are withdrawn from floodplains due to more frequent flood events or as a result of floods that generate a near-natural habitat structure.

1.7 Selected study catchments

The selected catchments, representing a north-south and a west-east gradient to ensure that different ecoregions and land-use intensities are covered, have been selected according to climatic, land-use, hydrological and hydromorphological data availability.

The selected study catchments general characteristics of catchment area, latitude, longitude and geographical location has been inserted in Table 1. The catchments are 6 lowland and 5 mountain, with catchments areas around 1000 Km^2, except from river Eman (Sweden) and river Neajilov (Romania), which have catchments area of 170 and 4460 Km^2 respectively.

Catchment	**Country**	**Catchment area (Km^2)**	**Latitude (degrees)**	**Longitude (degrees)**	Location
lowlands					
River Becva	Czech Republic	1524	49 29	17 30	Osek n. Becvou
River Vechte	Netherlands Germany	1968 (Dutch part)	52 17	07 14	Between Coevorden and Zwolle
River Dinkel (to Vechte catchment)	Germany	290	52 11	7 03	
River Emån	Sweden	4460	57 08	16 27	SE Sweden
River Lambourn	UK	263.33	51 24.30	01 18.20	South, central England, tributary of the Thames, west of London.
River Neajlov	Romania	3720	44 00	25 15	
mountains					
River Waldaist	Austria		48 19	14 34	
River Lahn	Germany	500	50 53	8 33	
River Eder	Germany	1200	51 06	08 35	
River Orco	Italy	650	45 20	07 44	Rivarolo Canavese
River Chiusella	Italy	171	45 24	07 55	Strambino

Table 1: WP2, Task 1.1 selected study catchments and their general characteristics.

Because each partner collected and analysed his own data, it was evident the need to use a common base for the format of the catchments general descriptions. During the 22-24 of November meeting, held in Wageningen, WP2, Task 1.1 partners decided to structure the catchments general descriptions as the WP2, Task 1.1 questionnaire, extended with problems and perspectives for the selected study catchment.

The principal treated arguments in each catchment general description are:

A. Climatic/discharge/land use scenarios:
Short description of local climatic/discharge and land-use scenarios expected in each model catchment.
Local problems for the catchment.

B. Climatic/discharge data:
Number and position of gauging stations and frequency of discharge measures.
Discharge time series availability.
Rain data type (rain, number of precipitation days, extreme daily precipitation, snow cover, runoff, etc.) and frequency of data record, number of stations and frequency of data collection in the catchment.
Other climatic data availability from the model catchment (air temperature, diurnal temperature range, Tmin, Tmax, evaporation, soil moisture).
Land use data

C. Hydromorphological survey method adopted:
Description of hydromorphological survey method adopted, list / description of the channel-features mapped.

D. Data analysis:
Land use data: description of data sources and of data analysis performed for analysis of relations between land use and hydromorphology.
Description of data analysis methods used to establish relations between land-use/discharge and hydromorphology (e.g. regression, pattern and multivariate analysis, hydromorphological model)?

E. Results
General description of results, hypothesis on hydromorphological features-land use relationships in each selected study catchment.

F. Perspectives, Cause Effect Chain and Cause Effect Recovery chain
Perspectives for the selected study catchment.
Hypothetical Cause Effect Chain expected, better reflecting the interactions between climate change and river hydromorphology through land use/discharge alterations in each model catchment (hydromorphological deterioration through intensification of land-use or through a more variable discharge regime that results in habitat modification and losses; or, alternatively, a significant improvement for the withdrawn of human disturbances from the floodplain due to more frequent flood events or as a result of floods that generate a near-natural habitat structure, etc.)?
Management measures which might be useful in improving channel morphology (Cause Effect Recovery chain) in each catchment (no reconstruction of regulation works destroyed by flooding, revitalisation of buffer strip zone, etc), e.g. from existing studies.

In Chapter 2 general catchments descriptions and preliminar results on climate-hydromorphology interactions through changes in land-use and discharge are reported for each of the following selected study catchments:

- Lambourn catchment
- Orco and Chiusella catchments
- Vecht catchment
- Dinkel, Lahn, Eder catchments
- Waldaist catchment
- Neajlov catchment
- Emå catchment
- Becva catchment

In Chapter 3 a 1-page summary of scenarios expected, collected data, data analysis, preliminar results, perspectives, cause effects chains and cause effect recovery chains, for each of the selected catchments is reported.

In chapter 4, in conclusion of this report, general remarks and comments on threated arguments and some notes on biological perspectives are reported.

2 STUDY CATCHMENTS GENERAL DESCRIPTIONS, CLIMATE-HYDROMORPHOLOGY INTERACTION ANALYSIS AND RESULTS

2.1 Lambourn catchment (UK)

John Murphy (NERC)

2.1.1 Scenarios

Local climatic/discharge alteration scenarios expected

We have not yet received the regional climate change model outputs from WP1 but predictions for southern UK generated by the UK Climate Impacts Programme suggest that the Berkshire region around the Lambourn catchment will be substantially warmer and marginally drier in summer by 2080 (Hulme et al. 2002). There may be more rainfall, and more frequent intense rainfall events in winter. The thermal growing season will be extended by 50-80 days as winters become less cold and spring arrives earlier in the year. Discharge regimes may be altered by these changes with summer flows reduced and more frequent droughts. Winter flows may increase with flood events becoming more frequent. Average annual soil moisture is predicated to drop by 10-20%, with particularly severe decreases in summer (Hulme et al. 2002).

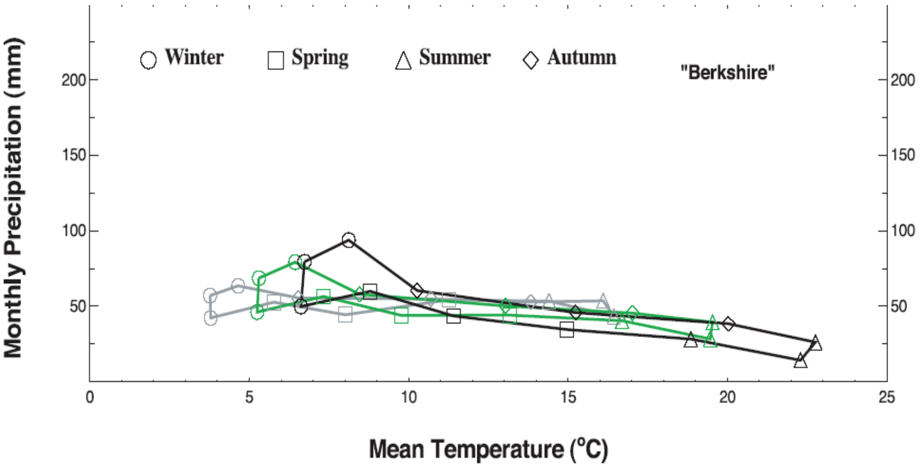


Figure 1. The changing seasonality of UK climate in the future. The seasonal variation in average temperature and precipitation for observed 1961-90 climate (grey),and for the 2080s as simulated for the **Low Emissions** and **High Emissions** scenarios. The monthly points are shown by different symbols for each season and these points join up to trace out the climate evolution of an average year (from Hulme et al., 2002).

Land use scenarios

Such changes could have profound affects on catchment agriculture. It is difficult to speculate on how floodplain land-use will change in response to projected climate changes. New crops will be introduced, along with new pests. Domestic, agricultural and industrial water use will become an even more pressing issue. Currently approximately 50% of the catchment is arable land (30% cereals, 20% horticulture). Improved pastures account for a further 25% of the catchment. More extensively managed grassland (6%) and deciduous woodland (9%) account for the majority of the remaining land cover. Within the 200m-wide riparian corridor the proportion of urban land and improved grasslands increases significantly (16% and 28% respectively). Extensively managed grasslands and deciduous woodland are marginally more prominent while arable land is less dominant (35%). Increased flooding frequency would result in a withdrawal of arable practices and urban areas from the floodplain and a reversion to extensively managed meadows. Alternatively, but less likely in my opinion, would be that flood defence works would be placed along the river corridor to maintain current agricultural practices and protect urban areas. Over the past 50 years the proportion of the catchment in tillage has risen dramatically, replacing improved pasture and semi-natural meadows as the most common land use. We will attempt to predict the consequences of a continuation in this trend and as an alternative the reversal of this trend.

2.1.2 Local problems

At the moment the catchment is relatively un-impacted. The main pressures on the river are from diffuse agricultural pollution and domestic waste. There is some abstraction of water for aquaculture towards the lower end of the catchment. The river is managed carefully to maintain a sustainable trout population as a commercial angling resource.

2.1.3 Collected data

Discharge

There are four discharge gauges in the catchment. There is Welford at the headwater of the catchment, East Shefford about half way down the catchment, Bagnor at the end of a tributary stream and Shaw near the mouth of the catchment.

Site	Period of record	Measurement frequency
Lambourn @ Welford	1962-1983	Daily mean discharge
Lambourn @ East Shefford	1966- 1983	Daily mean discharge
Lambourn @ Shaw	1962- present	Daily mean discharge
Winterbourn @ Bagnor	1962- present	Daily mean discharge

Rainfall

Lambourn Rainfall data is available for 6 sites distributed throughout the catchment and another close by site in a neighbouring catchment. The time period of the record and measurement frequency varies with site (see Table below). As well as rainfall the Meteorological Office record maximum and minimum air temperatures, soil temperature parameters, wind direction and speed and sunshine amount.

Site	Frequency	Period of record	Notes
Maddle Farm	Hourly	01/84-present	
Chieveley	Hourly	09/79-present	
Upper Lambourn	Daily	01/98-05/02	Closed now
East Shefford	Daily	11/63-present	
Peasmore House	Daily	01/61-present	
Priors Court	Daily	01/31-09/98	Closed now
Aldbourne (Kennet Catchment)	Daily	01/31-present	

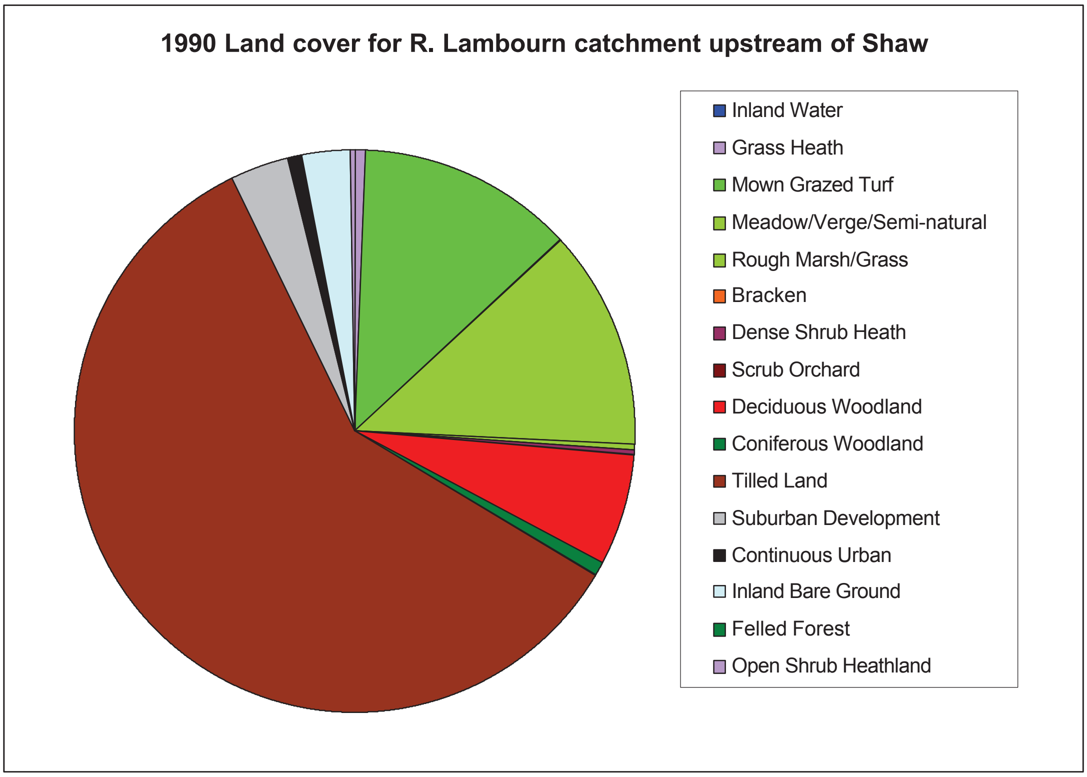
Hydromorphology

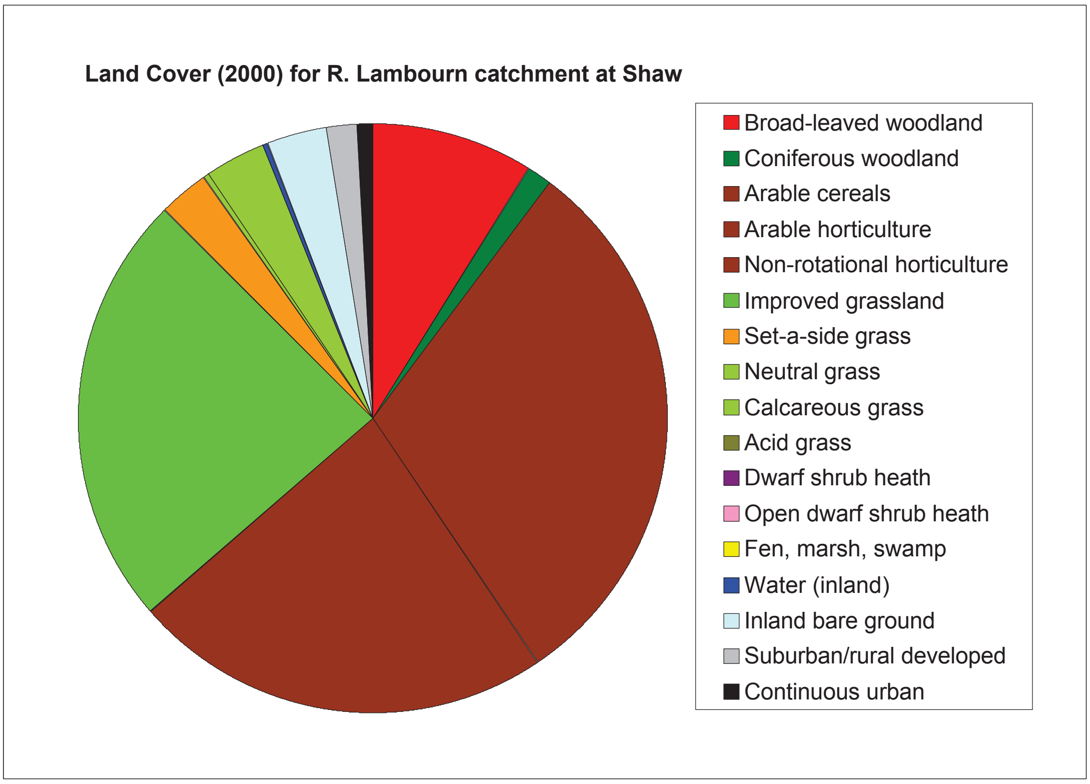
Hydromorphology has been surveyed at 25 500m sites along the 25 km length of the river Lambourn with two further sites on the tributary Winterbourne stream

The River Habitat Survey methodology has been used in all surveys. The following features of a 500m stretch of river are assessed:

- Flow type & diversity
- Channel substrate type & diversity
- Channel features
- Bank features
- Bank vegetation structure (bank face and bank top)
- Point bars
- Channel in-stream vegetation
- Land-use within 50m of channel
- Extent of riparian tree cover
- Extent of special features (e.g. large waterfalls, debris dams etc.)

Land-cover
Satellite-derived land-cover data has been acquired for the catchment from the 1990 Land Cover Map and the 2000 Land Cover Map. The 1990 and 2000 mapping projects did not use the exact same techniques and hence land-cover categories are not identical. This means that direct comparisons of change over time have be considered with caution. However if we standardise both surveys to the EUNIS Level 1 habitats then we can perform a more robust temporal comparison.





Apparent changes in the area of improved grassland may in fact be an artefact of the changes in definitions and techniques used between the two surveys. We would intend to use the LCM2000 data for spatial analysis with the RHS data.

2.1.4 Data Analysis

The hydromorphological information collected by River Habitat Survey is combined into Habitat Quality Scores. These scores can be presented at three nested levels (Fig. 4). The higher the score for any feature the more diverse and natural that trait is at the site. We related variation in Level 1 and 2 HQA scores across 25 RHS sites along the R, Lambourn to land cover at three different spatial extents; catchment, riparian corridor (200m wide zone upstream of site to source) and local area (250m radius around site) using multivariate ordination. We then related variation in Total HQA score to arc-sine transformed % land cover at three different spatial extents using multiple regression.

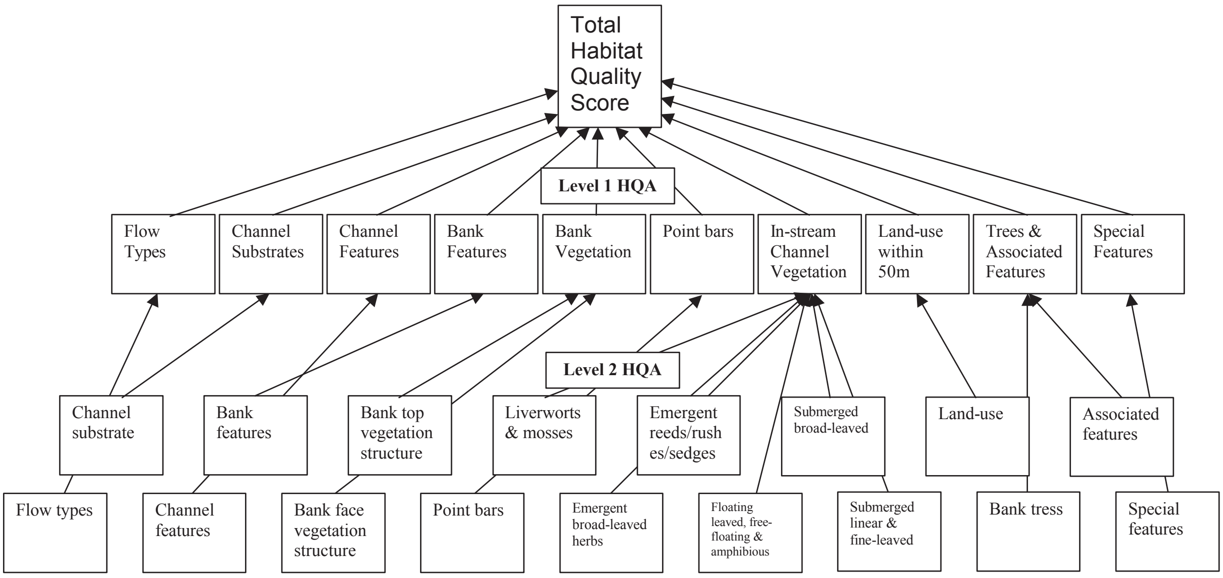


Fig. 4 River Habitat Survey Habitat Quality Score nested collation structure.

2.1.5 Results

Land cover at catchment, 200m riparian corridor and 250m-radius local area spatial extent was derived from the Land Cover Map 2000 GIS database. This data was converted to the EUNIS Level 1 Habitat classification. An initial investigation of variation in land cover longitudinally down the catchment revealed that at the catchment and riparian corridor scales, there was very little change between the sites (Fig 5). Therefore further analysis focused solely on the local area spatial extent.

Initial detrended correspondence analysis confirmed that a linear response model was appropriate for investigating the relationship between Level 2 HQA hydromorphological diversity and land cover. Subsequent redundancy analysis (RDA) found that 38.3% of the variation in Level 2 HQA scores could be accounted for by the statistically significant explanatory model defined by the % cover of Broad-leaved woodland, Arable (cereal) and Improved grassland within a 250m radius of the RHS site (Fig. 6). A greater cover of arable and improved grassland was associated with less than average scores for floating leaved, free-floating & amphibious vegetation, emergent reeds /rushes/sedges and bank-face vegetation structure. Broad-leaved woodland was associated with reduced Bank features scores and greater than average scores for Submerged, broad-leaved vegetation. Improved grassland was strongly correlated with a greater diversity of natural channel features but a reduced occurrence Bank top vegetation structure and bank-side trees. There was no clear longitudinal pattern in the relationship with sites close to the source and the mouth of the river clustering together in the RDA ordination space (Fig. 6).

An initial DCA on variation in the Level 1 HQA variables across the 25 sites showed a short gradient length suggesting that RDA would be an appropriate method to assess the relationship between site hydromorphological condition and land cover at the local scale. This analysis found that 47.1% of the variation in Level 1 HQA scores could be accounted for by the statistically significant explanatory model defined by the % cover of Broad-leaved woodland, Arable (cereal) and Improved grassland within a 250m radius of the RHS site (Fig. 7). This was an improvement on the Level 2 HQA variables relationship with local land cover suggesting the amalgamation of information to this level clarifies the relationship. Broad-leaved woodland are again associated with an increase in in-stream vegetation and a decrease in the prevalence of Bank features. Bankside vegetation and tress and riverbed substrate diversity seemed to be negatively affected by a greater occurrence of Arable (cereal) and Improved grassland in the local area around a site. However the converse is true for river channel feature and to a lesser extent flow diversity (Fig.7).

From these preliminary analyses it could be tentatively implied that any change to climate that caused a decrease in the extent of arable (cereal) and improved grassland in the floodplain could lead to a shift in river hydromorphology from sites characterised by a diverse range of flow types, emergent herbs and submerged, fine-leaved plants to sites featuring more emergent reeds, floating and free-living amphibious plants and greater bank face vegetation structure.

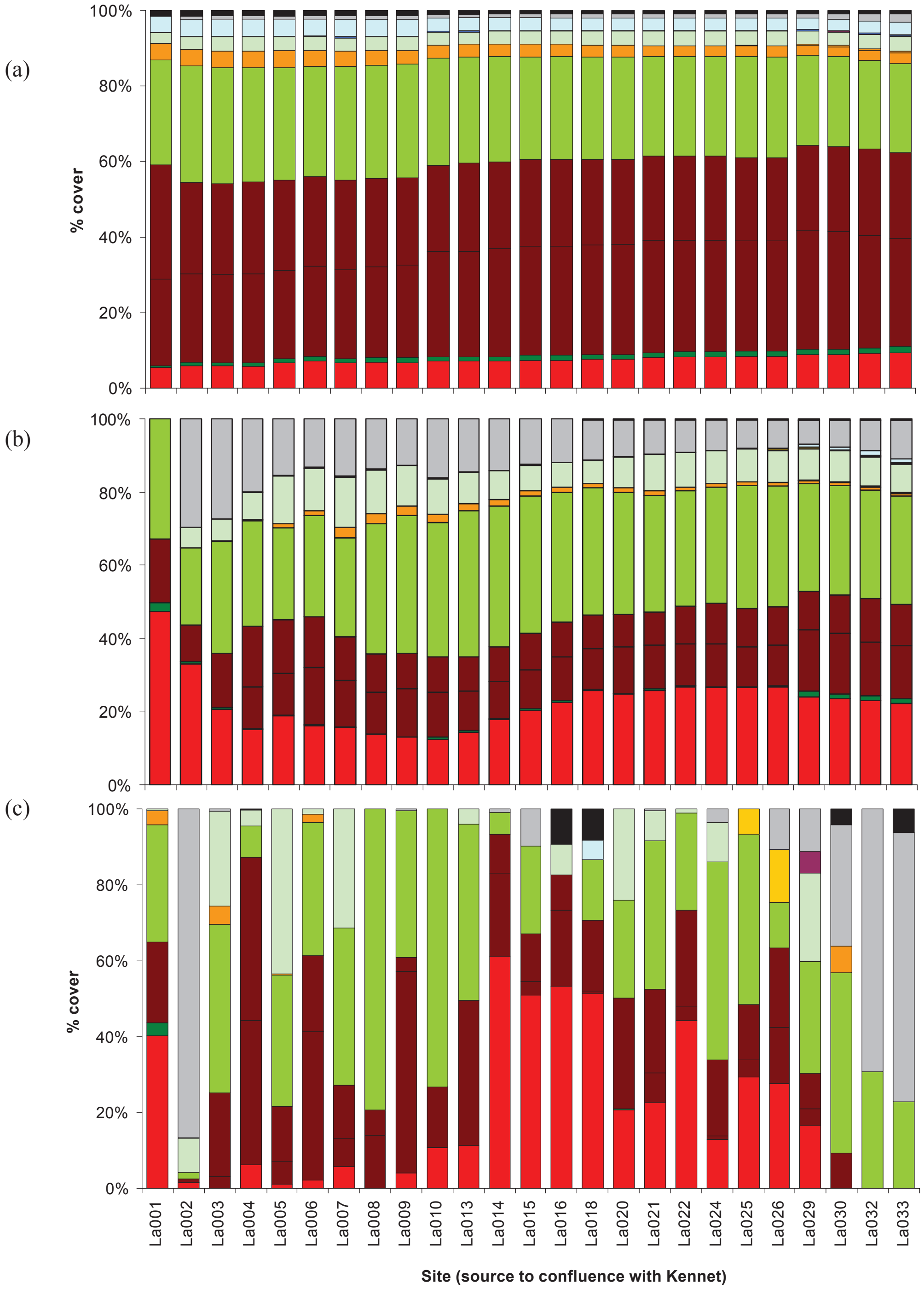


Fig. 5 Longitudinal land cover change within the R. Lambourn at (a) catchment scale, (b) riparian corridor scale, and (c) local scale. Sites are arranged from source to mouth, left to right. Key to Land Cover Map 2000 land cover categories is that shown in Fig. 3.

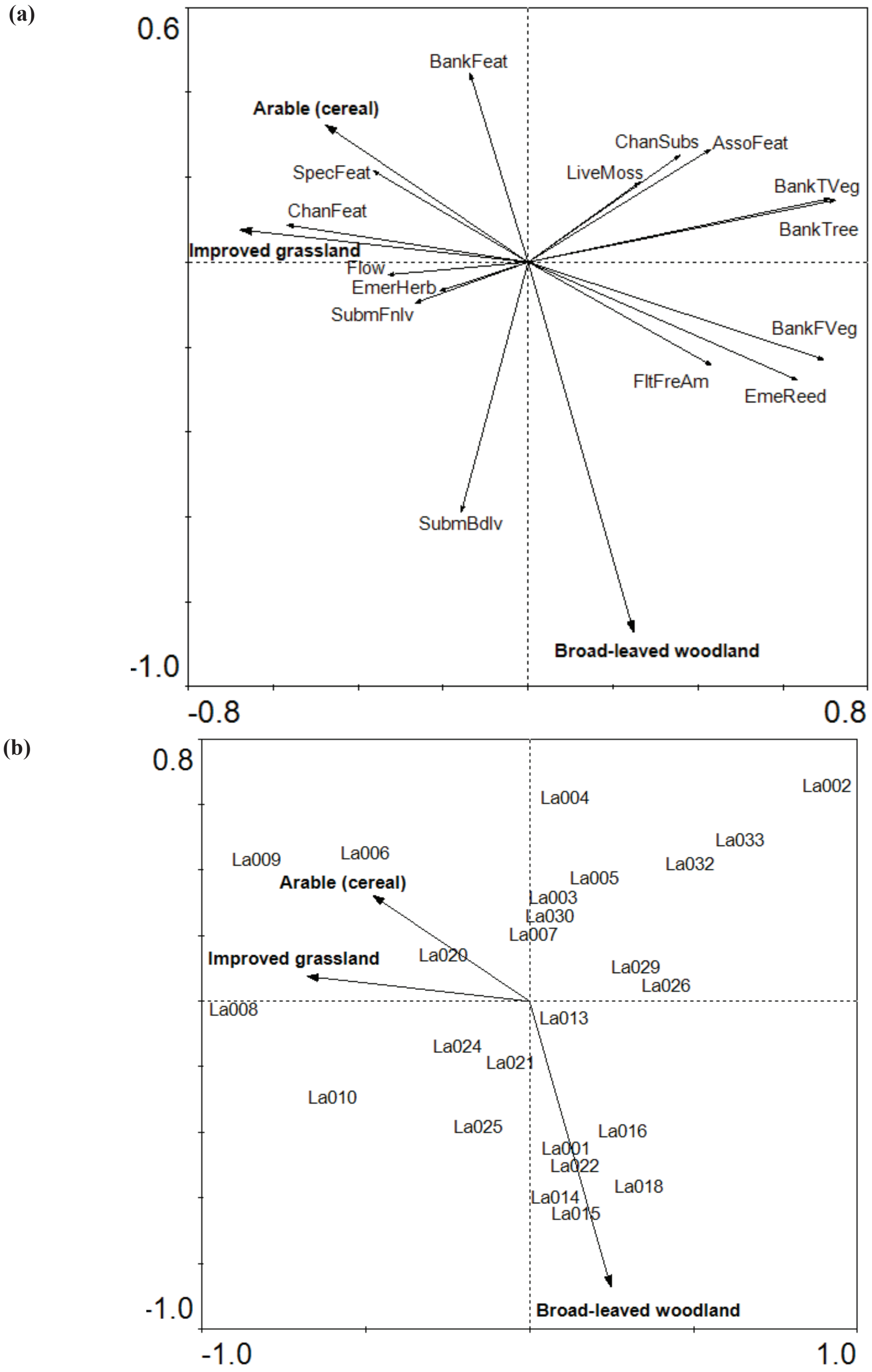


Fig. 6 Redundancy analysis (a) species and (b) sample biplots illustrating the relationship between the Level 2 HQA scores species dataset and the LCM2000 local land cover across 25 R. Lambourn sites.

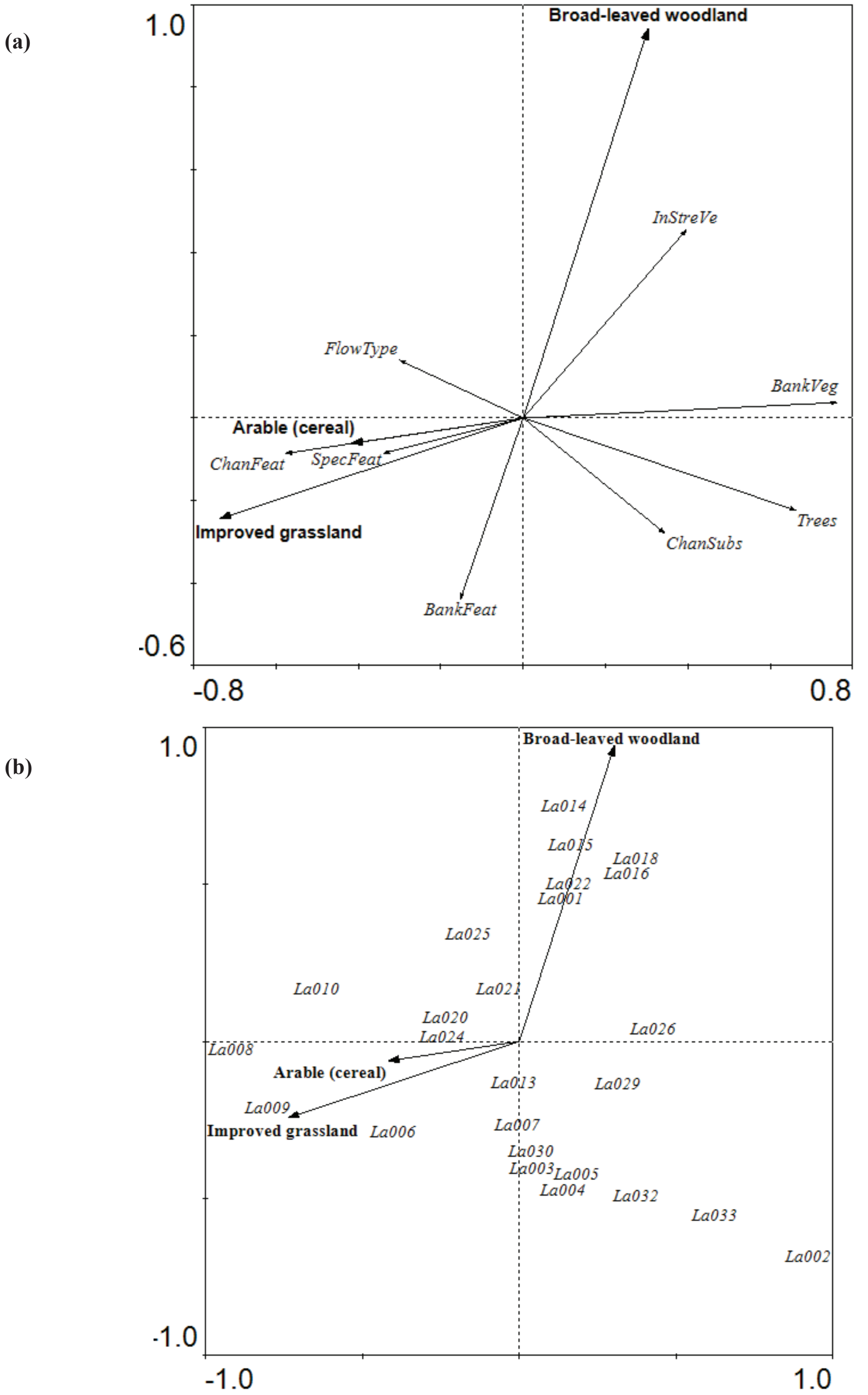


Fig. 7 Redundancy analysis (a) species and (b) sample biplots illustrating the relationship between the Level 1 HQA scores species dataset and the LCM2000 local land cover across 25 R. Lambourn sites.

2.1.4 Perspectives, Cause Effect Chain and Cause Effect Recovery chain

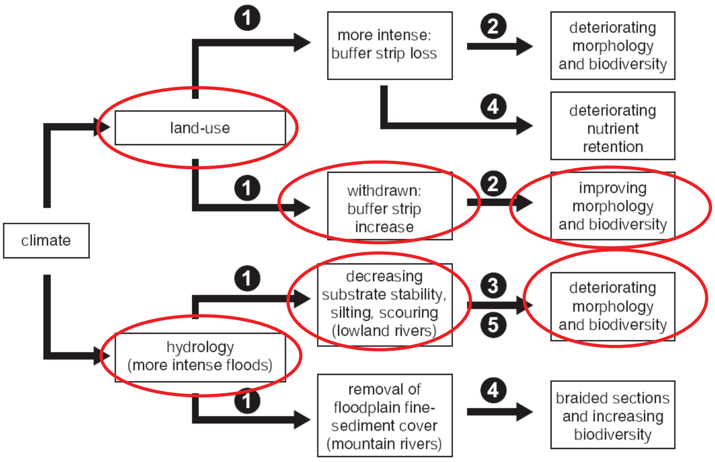


Figure B.4.3: Cause-Effect Chain for climate impacts on river hydromorphology

I would speculate that projected climate change for the Lambourn region would lead to more frequent and more severe summer droughts and more frequent and intense winter floods. This will cause an increase in substrate erosion and transport in winter but conversely an increase in fine sediment deposition in summer. From recent studies in the Lambourn it may be that the summer droughts and associated physical changes to the river hydromorphology would have a more detrimental impact on the biota than winter floods (Wright *et al*. 2004). Also the projected climate change will lead to changes in catchment land-use, in particular on the floodplain. I would speculate that there would be a withdrawal of intensive arable agriculture from the more frequently flooded riparian corridor and a reversion to wet meadows and grazing pastures and perhaps even an increase in wet woodlands.

A recent publication by Wright et al. (2003) outlined the impact of changes in trout fisheries habitat management practice on the riparian vegetation of the R. Lambourn at Bagnor. Reductions in management intervention (in-stream weed cutting, riparian tree pruning, clearance of bank side vegetation for ease of access) lead to greater shading and changes in the macroinvertebrate community and hydromorphology of the site.

Temporal changes in a series of habitats and their macroinvertebrate assemblages were examined on a 50-m section of a chalk stream in Berkshire, England between June 1975–79 and June 1997–2001. The site was part of a trout fishery in 1975–79, when river management included instream weed cutting together with control of bankside trees and riparian vegetation. Management ceased in the 1980s and by 1997–2001, the site was heavily shaded by trees and riparian vegetation. The mean area of instream macrophytes decreased by 50% between the first and second sampling period. In contrast, gravel and silt increased and invading marginal vegetation formed a new habitat. Changes in macroinvertebrate family richness between sampling periods were scale dependant. Although there were, on average, significantly more families in individual replicates in 1975–79 than in 1997–2001, total family richness for the site in each year did not differ significantly between sampling periods. Sixty families of macroinvertebrates were recorded during the study, 50 in both sampling periods, 53 in 1975–79 and 57 in 1997–2001. This small increase in site family richness may be due to the invading marginal plants. Total macroinvertebrate abundance was significantly lower in the second sampling period. A major drought in 1976 resulted in significantly higher densities of macroinvertebrates, partly through the exploitation of epiphytic diatoms by chironomid larvae. A drought in 1997 failed to elicit a similar response because of the limited macrophytes and diatoms under heavy shading by trees and marginal vegetation. Significant increases in important shredders and decreases in some scrapers between the early and later sampling years largely reflected changes in available food resources.

Whereas macroinvertebrate family richness has been conserved under the recent 'no management' regime, the site is now less attractive as a fishery because of poor access and lower densities of some macroinvertebrates taken by brown trout.

The macroinvertebrate assemblages of three unshaded sites on the River Kennet and one shaded site on the River Lambourn in Berkshire, England, were sampled in summer 1997-2001. Quantitative samples were taken on gravel and on the dominant macrophyte at each site in each year and abundance data were recorded for 57 families of macroinvertebrates. The study commenced during a major drought (1997), but in subsequent years discharge prior to sampling was much higher, culminating in the exceptionally high flows of spring 2001. Both family richness and abundance varied significantly in relation to site, habitat and year. Multidimensional scaling ordination, based on Bray-Curtis dissimilarities, also displayed significant differences between sites, habitats and years. Differences in composition between the Kennet sites were partly due to longitudinal zonation whilst on the Lambourn, faunal differences resulted from shading and the addition of families from nearby habitats, including marginal vegetation. Major changes took place in family composition and abundance between the drought year of 1997 and 1998, indicating that faunal recovery from drought was rapid. Thereafter, faunal changes between 1998 and 2000 were relatively limited. In 2001, following the prolonged period of exceptionally high discharge, overall family richness peaked on both habitats at the three Kennet sites and family abundance reached peak or second highest values on all four sites and both habitats. Thus, the recent high discharge regimes experienced by these perennial chalk stream sites have had no immediate detrimental consequences for the macroinvertebrate assemblages.

2.1.5 References

Hulme M., G.J. Jenkins, X. Lu, J.R. Turnpenny, T.D. Mitchell, R.G. Jones, J. Lowe, J.M. Murphy, D. Hassell, P. Boorman, R. McDonald & S. Hill, 2002. *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

Wright J.F., R.T. Clarke, R.J.M. Gunn, J.M. Winder, N.T. Kneebone, & J. Davy-Bowker, 2003. Response of the flora and macroinvertebrate fauna of a chalk stream site to changes in management. *Freshwater Biology*, 48, 894-911.

Wright J.F., R.T. Clarke, R.J.M. Gunn, N.T. Kneebone & J. Davy-Bowker, 2004. Impact of major changes in flow regime on the macroinvertebrate assemblages of four chalk stream sites, 1997-2001. *River Research and Applications*, 20 (7).

2.2 *Orco and Chiusella catchments (Italy)*

Carlotta Casalegno and Andrea Buffagni (CNR-IRSA)

2.2.1 Geographic area

Orco and Chiusella catchments are situated in North Western Italian Alps, in Piemont region. Piemont lies in a peripherical position with respect to the rest of Italy but its relative proximity to the sea and contact with France and Switzerland have, over the centuries, led to the creation of an important commercial transit network which has favoured its present economic development. This is the largest region of continental Italy, second only to Sicily. Its density of 174 inhabitants per sq km makes it the fifth most densely populated region in Italy, and slightly under the national average. The Italian regions which border with Piemont are Valle d'Aosta to the northwest, Lombardy to the east, Emilia-Romagna to the southeast and Liguria to the south. Piemont includes almost the entire upper section of the Po River catchment basin, ie., the plain above the Ticino, Sesia and Scrivia rivers and the surrounding Apennines and Alps. The Piemontese Alps rise as mighty massifs which, at some points, soar to over 4,000 m. (Mount Rosa, 4,633 m.; Gran Paradiso, 4,061 m.). The transition from this mountainous region to the plain is marked by a discontinuous belt of morainic high ground which does not detract from the impression of clear contrast between the encircling mountains and the plain which in fact lies at the foot of the mountain. The climate is prevalently continental, with high seasonal and daily ranges of temperature; the winters are long and cold, and foggy on low ground; the summers are hot and sultry in the flat areas, cooler in the hills and mountains. Rainfall is highest in autumn and spring: the wettest areas are western Verbano, Cusio, the Biella area, Upper Valsesia and Ossola (1,500-2,000 mm./year).

Forests cover a total of 590 thousand hectares and there are a great many protected areas. In the alpine zone, the larch and chamois can be considered the symbols of this region. The larch is the only tree which can flourish well above 2,000 m. and the only conifer that sheds its leaves in winter.

Apart from the Po and Ticino, the waters of the Piemontese rivers vary in volume and are mainly torrential.

Orco catchment is 910 km2: 78% in mountain area and 22% in lowland area; 11% occupied by glaciers. The river Orco flows for 90 km form the southern side of Gran Paradiso massif to its Po confluence at Chivasso. The river Orco springs are in Lake Rosset (2780 m asl) and its main tributary is Soana stream which confluences at Pont Canavese (46 Km downstream from the source). In Orco catchment 6 dams for hydroelectric power are present and the major villages are Rosone, Locana, Pont Canavese, Cuorgnè, Castellamonte, Rivarolo, Feletto, Bosconero, San Benigno and Chivasso. Chiusella catchment, situated at east side of Orco catchment, is 480 Km2. The river Chiusella flows for 40 Km, from the source (2600 m asl) to its Dora Baltea confluence, in a less disturbed valley. In Chiusella catchment 1 dam for hydroelectric power is present and the major villages are Traversella, Issiglio and Perosa canavese.

2.2.2 Scenarios

To predict the effects on hydromorphology of two different potential changes in land-use following climate change, we used existing data on climate change simulations extracted from different bibliographical sources. Orco catchment climatic scenarios have been extrapolated from South European scenarios extracted from the Rossby Centre climate change simulations (Räisänen et al., 2003), reporting a set of regional climate change simulations representing the climate in the late 21 st century (2071-2100). This scenarios have been completed with information on climate peculiar characteristics and on precipitation trends on the Alps (Frei & Schar, 1998; Frei et al., 2003; Schmidli et al., 2002) and in Northern Italy (Brunetti et al., 2000).

Data on the simulated effects of climatic change on European hydrological behaviour have been extracted from an investigation (Arnell, 1999) on the effects of climate change on European water resources.

Climatic scenarios

Under all scenario simulations a general warming is predicted. In particular in central and southern Europe, the warming should peak in summer, reaching locally 10°C. The warming will be associated with substantial decreases in soil moisture, cloudiness and, as expected, it will be accompanied by reduced snow cover. In North Western Italy, a decrease in mean annual precipitations, should be expected. A decrease in mean daily precipitations (50-70%) and in the total number of precipitation days should be expected specially in summer, an increase in extreme precipitation events (Brunetti et al., 2000), even in most of those areas where the time mean precipitation decreases, should be expected, in autumn-winter.

The summertime warming and drying in central and southern Europe, combined with the increase of extreme events might have serious consequences on rivers hydromorphology. It is therefore important to integrate different knowledge (hydrological, hydromorphological, substrate/habitat stability, biological, climatic data) for the assessmemt and management of climatic changes impacts on freshwater ecosistems.

Hydrological scenarios

According to climate scenarios expected, in study catchments the winter discharge should increase due to reduced snow and increase in rain precipitations. Accordindg to this, a change in the timing of flows (due to reduced snow cover), with a shift from a winter minimum to a late summer minimum and a more dynamic discharge regime, due to increases in extreme daily precipitation, should be expected.

Land use scenarios

To study the effects of climate changes on land uses and to picture future hypothetical scenarios it is necessary to focus on the core current land uses which depend from a combination of socio-economical-environmental factors. In Orco and Chiusella catchments the % cover of core current land uses, according to 2000 Corine Land Cover data, are Forest and semi-natural areas, 76% in Orco and 59% in Chiusella catchment, Agricultural, 38% in Chiusella and 22% in Orco, Artificial, 2.8% in Chiusella and 1.5% in Orco.

In the selected catchments the forest cover (as reported in Piedmont Region “Piani Territoriali Forestali”, PTF) is mainly composed of the deciduous trees: Salix, robinia (*Robinia pseudoacacia),* poplars (*Populus nigra*), ashes (*Fraxinu*s), alders (*Alnus*), elms (*Ulmus*), birches (*Betula)*, acers (*Acer*), European hornbeam (*Carpinus*), oaks (*Quercus*), chestnuts (*Castanea sativa*).

The information collected from agricultural local authorities (Agricultural Association, Consorzio Agrario, in Rivarolo), evidence that actually the agricultural production system is characterized by maize (*Zea mais*) intensive agriculture, which accounts for 90 % of the total cultivations, with the remaining part constituted by grain, 7-8 %, and by soybean, barley, pea (*Pisum sativum*), avena, 2-3%.

As evidenced by local authorities (Turin Province, Agriculture Office), the EU financed Community Agriculture Policy (PAC) is the most important tool to manage land use in Europe and on a short time scale perspective the actual predominance of monosuccessional maize (*Zea mais*) cultivation should go throughout a reduction to come back to soybean, barley and wheat (*Triticum aestivum*) cultivations, owing to three reasons:

1 the accumulation of nitrates used as fertilisers in maize cultivation
2 contamination deriving from herbicides required in maize cultivation
3 the progressive spreading in North Italy of the pest *Diabrotica virgifera virgifera* Le Conte (Insecta: Coleoptera: Chrysomelidae).

Predictions on land use scenarios are referred to a longer time scale and they must consider interactions among different factors with climatic changes.

The vegetation response to changes in climate is of great economic, social and ecological interest. Distribution of forest trees species are largely controlled by the soil moisture balance then climate change could lead to shifts in their distributions. Moreover, as noted in Sierra Nevada (Miller & Urban, 1999), climate change could increase the frequency and the spatial extent of wildfires. Owing to this, in Mediterranean countries the fire risk could increase during summer for mediterranean vegetation and during winter for alpine forests. The climate mediate disturbances such as fire can shorten the lag in forest response, 100-200 years behind an abrupt climatic change (Davis & Botkin, 1985), resulting in very complex forest response to climatic change.

The deciduous species response to warming in the italian study catchments could be a farther north or uphill moving, depending on each species environmental tolerance, accompanied by a loss of biotic diversity, increased tree mortality and expansion of exotic species.

Climate and meteorological weather are still key factors in influencing agriculture productivity despite technological improvements. The combined effect of higher atmospheric CO2 concentrations, temperature and rain variability, higher sea levels, has been little studied in Italy. Moreover, despite the general agreement on future warming, it is very difficult to predict agricultural land uses scenarios for the incertanty in precipitation tendency, which is the key factor influencing agriculture activities from medium (around 45° latitude) to low latitudes. Has been evidenced that the warming reduce maize and wheat production and if combined with lower precipitations their production could decrease of 20%. Land use scenarios referred to 2060 indicate that the effects of climate change are mainly felt through changes in the distribution of crops which will concentrate in areas best suited to it and a general tendency to a reduction of the area under agricultural production, owing mainly to the increases in yield of crops and grass through technological improvements (Hossell et al., 1996).

Owing to this, in Orco and Chiusella catchments a decrease of agricultural areas, due to reduced precipitations, is the expected land use scenario. The reduction of agicultural areas could be accompanied by an increase of forested areas which could interact with the expected urban growth.

2.2.3 Local problems

The mean annual precipitations range from 900 mm to more than 1800 mm. The north-south orientated valleys of Orco and Chiusella catchments are exposed to wet currents coming from south, making them subjected to intense precipitations fro most part of the year. Consequently high discharges and floods are frequent (10 recorded events from 1953 to 2000) specially in autumnn and spring and often have great impact on human activities in the catchments.

Locally the climatic changes could be felt throught an increase of such extreme events, with more frequent and intense floods, specially in autumn and spring, with an intensification of damages on human activities in the catchments. Moreover higher temperatures could lead to a change in timing of flows, with a shift from a winter minimum to a late summer minimum and an increase in severity of droughts in summer.

The expected demographic grown will have a greater impact on the upstream sections of the catchments: the limitated space availability in the upstream sections will make areas near to the floodplain the only spatial resource available.

2.2.4 Collected data

Discharge

There are three discharge gauges in the selected catchments (data source, Regione Piemonte). One (Parella) is in Chiusella catchment, near the confluence of Chiusella stream with Dora Riparia stream, 28 Km from the source.

Soana and S. Benigno discharge gauges are in Orco catchment. Soana Pont is situated in the upper part of the Orco cacthment at the end of a tributary stream (Soana stream) and S. Benigno is in the lower part of the cacthment, at 76 Km from the source, near the mouth of the catchment (at Orco confluence with Po river).

Site	Period of record	Measurement frequency
Chiusella Parella	2002-2003	Daily mean discharge
Soana Pont	2002-2003	Daily mean discharge
Orco S. Benigno	2002-2003	Daily mean discharge

Rainfall

Orco and Chiusella catchments rainfall data are available for 9 sites distributed throughout the catchments (Data source: Piedmont Region). 7 sites are in Orco cathment and 2 sites are in Chiusella catchment.The time period of the record varys with site (see Table below) and the parameters recorded are rain data (mm) and number of precipitation days. As well as rainfall data the Meteorological Office of Regione Piemonte records wind direction and speed, sunshine amount, maximum, mean and minimum air temperatures and mean wettedness.

Site	Frequency	Period of record	Parameter
Belmonte	Monthly	1997-1999	Rain (mm), Number of prec. days
Bertodasco	Monthly	1990-1999	Rain (mm), Number of prec. days
Ceresole	Monthly	1999	Rain (mm), Number of prec. days
Agnel	Monthly	1996-1999	Rain (mm), Number of prec. days
Audi	Monthly	1996-1999	Rain (mm), Number of prec. days
Pianprato	Monthly	1993-1999	Rain (mm), Number of prec. days
Valsoera	Monthly	1990-1999	Rain (mm), Number of prec. days
Traversella	Monthly	1996-1999	Rain (mm), Number of prec. days
Colleretto	Monthly	1999	Rain (mm), Number of prec. days

Hydromorphology

The River Habitat Survey modified for South Europe (RHS SE) methodology has been used in hudromorphological surveys. The River Habitat Survey (RHS) method was chosen for adaptation to the Italian and South European situation because of its wide range of possible outcomes and for the objective approach in describing the riverine environment (Buffagni & Kemp, 2002).

Data have been collected in July/August/September 2004 at 23 sites, 18 in Orco cacthment and 5 in Chiusella catchment (Table 1, Figure 1, Figure 2), situated every 2-3 Km along selected river reaches. Orco river has been surveyed along a 40 Km reach, situated between Rosone, 685 m above sea level, 48 Km from the source and the Po confluence, 192 m asl, 86 Km from the source; Chiusella along a 12 Km reach, between Traversella, 471 m asl, 20 Km from the source and Perosa canavese, 225 m asl, 32 Km from the source.

In each site, observations are made at ten equally spaced spot-checks along a standard 500m lenght of river channel: a total of 230 spot-checks (180 along Orco and 50 along Chiusella river) were surveyed.

Table 1. Stream type and general characteristics of selected study sections.

Stream name	stream type	River system	Ecoregion (according to WFD)	Catchment size (Km2)	Altitude (m a.s.l.)	Number of sections (500 m length)
Orco	Mid altitude, mid-sized alluvial stream	Po	3	470-882	192-685	18
Chiusella	Mid altitude, mid-sized alluvial stream	Dora Baltea	3	390-490	225-471	5

As in the RHS method, the RHS SE recorded features are:

- Bank features
- Bank vegetation structure (bank face and bank top)
- Land-use within 50m of channel
- Extent of riparian tree cover
- Extent of special features (e.g. large waterfalls, debris dams etc.)

The novelty of the RHS SE method consists in the record of the following channel features in the principal and in the secundary channel:

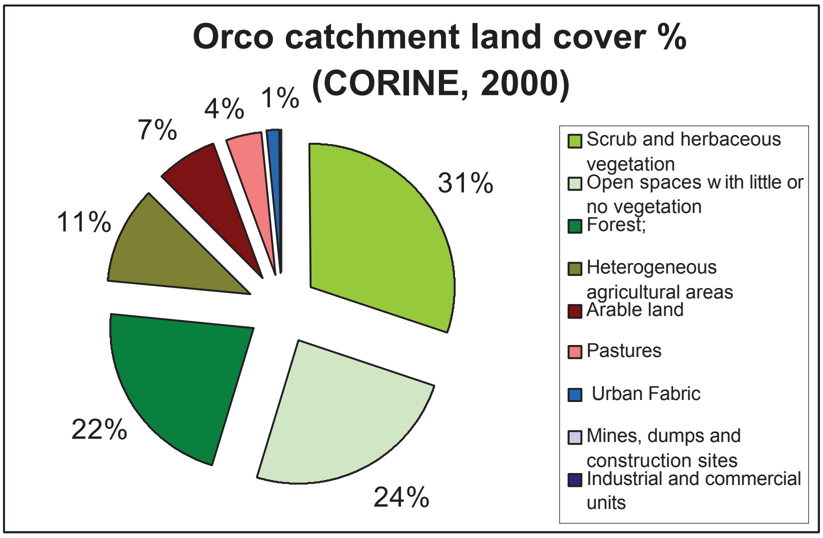
- Flow type & diversity
- Channel substrate type & diversity
- Channel modifications
- Bars (side bars, point bars, concave bars, multiple bars)
- Channel in-stream vegetation

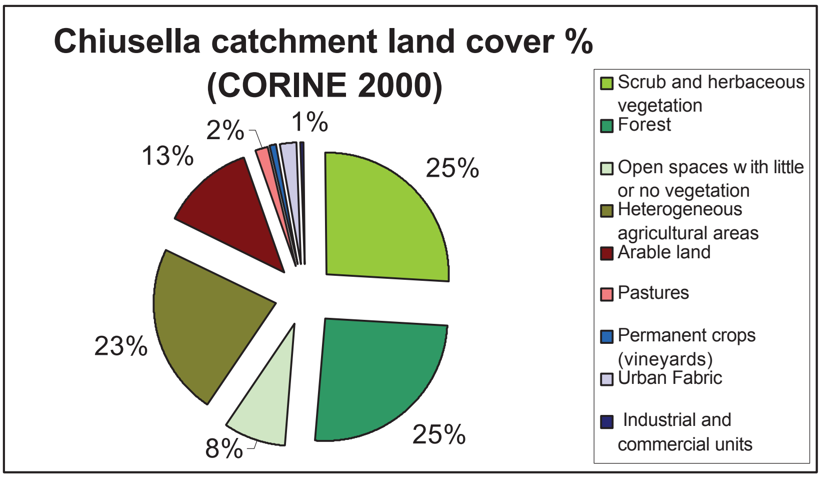
Moreover, the following new data are recorded with the RHS SE form:

- Microhabitat extent and position
- Number of active channels
  - Channel position (Left-Center-Right)
- Straight or curved reach
- Water widht and max water depth

Land Use data

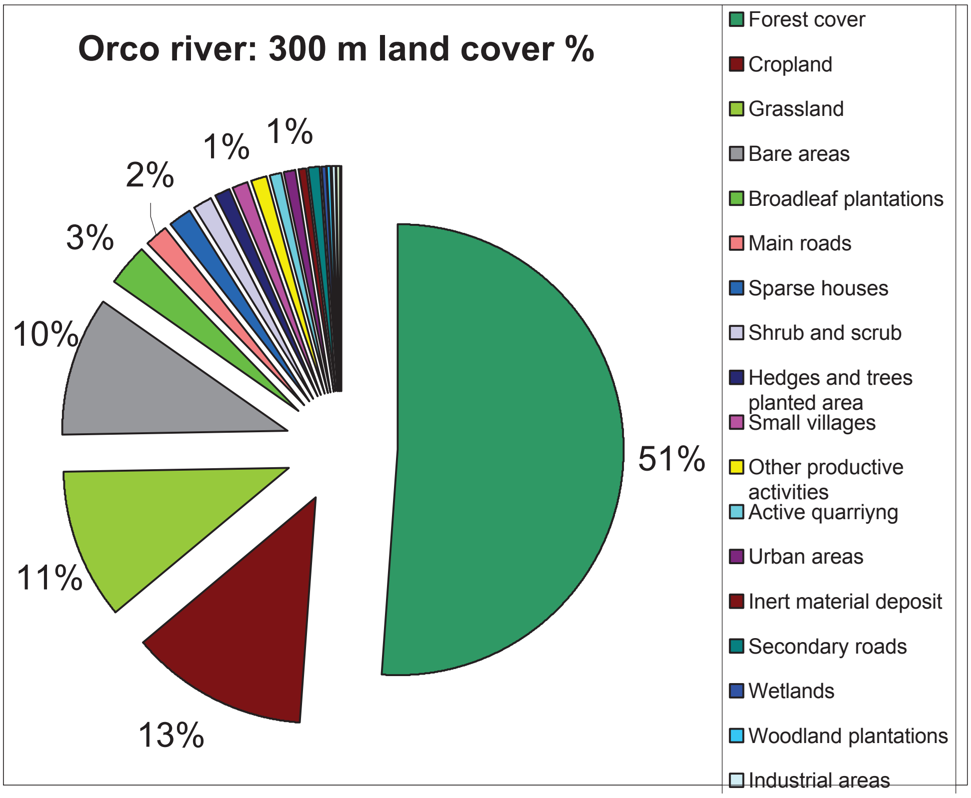
Land-cover data has been acquired for Orco and Chiusella catchments from the the 2000 CORINE Land Cover Map. The resulting % cover are (Level 3 categories, CORINE):





For Orco river reach comprised between Pont Canavese and the Po confluence, land use data referred to an area extending 300 metres along each river bank, extracted from a GIS project furnished by Piedmont region (ARPA Piedmont), are also available.

The applied methodology consists in the use of a photointerpretation of digital ortophotos (with a 1:10000 scale, referred to the year 2000 situation) of riparian area characteristics on a 300 metres wide area from each bank. The % cover in the 300 m wide area of the studied river reach are:



2.2.5 Data analysis

To separate sections with different hydromorphological characteristics pattern and multivariate analysis were performed on collected data. The aim is to develop a simple predictive model to relate land use-hydromorphology-meso/microhabitat characteristics using RHS SE collected data and land use percentages cover at different spatial scales (from catchment to site scale).

Land use data processing

Hypothesis: land-use near the channel is more influential on hydromorphology compared to land-use far away from the stream section. To test this hypothesis, land use percentages cover referred to different “spatial scales or spheres of influence” were defined in each 500 m river reach surveyed with RHS SE method:

- RHS SE land use data, referred to near channel area (≤300 m)
- 300 m land use data, referred to 300 m wide area along each river bank (collected from ARPA Piedmont)
- lateral catchment land use data, referred to the area extending laterally from the river surveyed sites to the catchment borded (Corine, 2000)
- sub-catchment land use data, referred to % land cover in each subcatchment (Corine, 2000)
- catchment land use data, referred to whole catchment from the source to each surveyed site (Corine, 2000).

Except for land use data referred to near channel area, which were extracted from RHS SE form, and 300 m data which were furnished by Piedmont region, percentages of lateral, sub-catchment and catchment land use percentages were calculated on shape-files digitalized by hand with Arc view 3.2.

Statistical analysis

A multivariate analysis was performed with Canoco for Windows Version 4.02 on land use and hydromorphological data collected in the 22 selected sites (18 along Orco and 4 along Chiusella river. Chiusella sampling site situated in the artificial lake at Vidracco dam has been excluded from the analysis). In this analysis the percentage of occurrence of hydromorphological features recorded with RHS SE method has been used as dependent variables and percentage area covered by different land-use categories calculated for five spheres of influences as independent variable. Percentage area data were arcsin transformed (arcsin $(X)^{0.5}$) (Podani, 2000) and CORINE land use categories inserted in the analysis were Level 1 and Level 3. Sample sites altitude and catchment area were threated as independent variables, distance from the source as covariate.

A Detrended Correspondence Analysis (DCA) was performed for the hydromorphological data to determine the lenght of the gradient, which resulted = 3, consequently a Principal Component Analysis (PCA) was used to investigate the relation between the hydromorphological parameters and land use parameters. Because of the great number of hydromorphological variables (around 380) and the low number of sites (22) and to separate hydromorphological variables according to their spatial scale, we performed separate PCA analysis for grouped data sets of hydromorphological variables: erosion/depositional features, bars, substrates and flow types. The groups of hydromorphological features analysed were:

Depositional/erosional features (macro/mesoscale)
- Midchannel, side and point bars (vegetated and non vegetated), channel deposits (sand, gravel and silt);
- eroding and stable cliffs, eroding banks.

Bars (mesoscale):
- Midchannel, side and point bars (vegetated and non vegetated).

Flow types and substrates data recorded at spot-checks (microscale)

Flow types and substrates data recorded at section K (microscale).

Pattern analysis was performed with STATISTICA, Version 5.0: Percentiles/Box-Whisker Plots on single highly predictive parameters evidenced by PCA were used to separate sites with different hydromorphological state.

2.2.6 Results

Depositional/Erosional features

As showed in Table 2, first PCA ordination axis accounts for 31.12% of total variance of depositional/erosional variables recorded in 22 surveyed sites in Orco and Chiusella catchments. The variables best representing the gradient along this axis are hydromorphological features characteristic of dynamic river reaches, as channel deposits (sand and gravel deposits), not vegetated bars (side and midchannel bars) and features reflecting more stable river reaches, as vegetated bars (point, side and midchannel). Consequently the ordination along this axis can be interpretated as a river reach stability gradient.

The land use categories more correlated to unstable river reaches at site scale (300 m and RHS scale) are indicative of areas which periodically could be submerged by river floods: broadleaf plantations and tilled land (Table 2). At catchment scale the presence of beaches, dunes, sand, and mineral extraction sites is correlated to river instability. It is interesting to note that the presence of beaches, dunes, sand at catchment scale is correlated with deposits recorded ad RHS scale.

Land uses which can be considered more stable, sparse houses, orchard at site scale and complex cultivations, at intermediate scale (lateral), are correlated to stable river reaches.

The second PCA axis, accounting for 18.77% of total variance, has been interpretated as curved-straight river reach gradient. Side bars (both vegetated and unvegetated), typical of straight river reaches, opposed to point bars and eroding cliffs, typical of curved river reaches, lead to this interpretation. The % of SC in straight river reaches, recorded with RHS SE, is the variable more correlated with this axis ($r = 0.69$). Land use categories more correlated to straight river reaches are industrial and urban areas at intermediate (lateral) and site (300 m) scale. The percentage of area covered by broad leaf at intermediate scale (Figure 1), resulted to be significatively different in straight and curved river reaches. This result evidence as near urban areas the river channel has been often straightened.

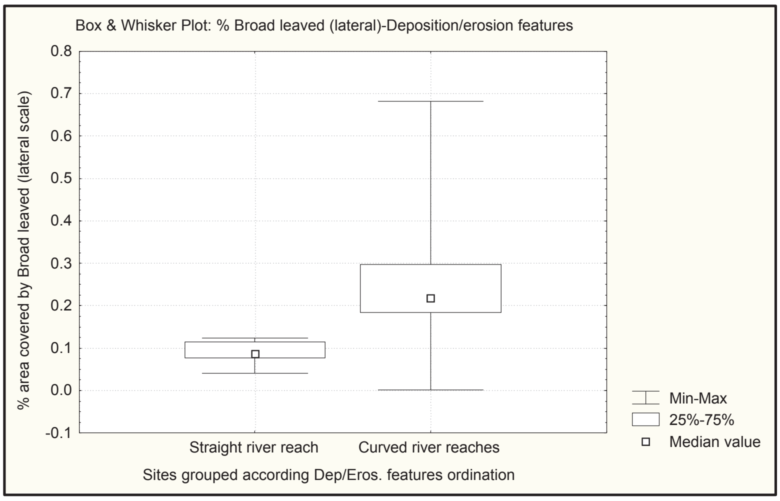


Figure 1: % lateral area covered by Broad leaved in sites grouped according to their straight/curved character (site scores referred to the second PCA ordination axis of depositional/erosional features).

Bars

The first two PCA ordination axes, accounting for 31.9 and 24.7% of total variance observed in bars typology, can be interpretated as for depositional/erosional variables ordination axis, referred to a smaller spatial scale. The first axis reflects a stable-instable substrate structure and the second axis a straight-curved river reach gradient. The variables best representing the gradient along this axis are not vegetated bars (midchannel and side bars), characteristic of unstable substrate structure, and vegetated bars (midchannel and point bars) reflecting more stable substrate structure. Land uses more correlated to this axis evidence as natural land uses (sparsely vegetated areas, coniferous forest) are more correlated to unstable subtrate structure and urban/artificial substrates are more correlated to stable substrate structure. The HMS index correlation with this axis evidences as in the selected catchments the presence of vegetated bars, consequently a stable substrate structure, is often linked to the presence of man induced modifications.

The second axis separate straight, characterized by the presence of midchannel and side bars, from curved river reaches, where point bars are present. Land use categories more correlated to this axis are referred to site scale. Orchard, recorded at RHS scale, is correlated to straight river reaches and scrub and shrub, at 300 m scale, is correlated to curved river reaches.

Flow types and substrates

Section K

First PCA ordination axis accounts for 24.27% of total variance of flow types and substrates recorded in surveyed sites 500 m river reaches. The ordination along this axis separate microscale characteristics according to their natural-artificial characteristics (recorded under section K natural/artificial). The presence of grassland at site scale (300 m) is correlated to artificial microhabitat characteristics. Moorland and broadleaf plantations, recorded at subcatchment and 300 m scale, are correlated to natural microhabitat characteristics. This result evidences as in the selected catchments microscale artificial characteristics are influenced by site scale land uses, natural characteristics are influenced by subcatchment land use.

The second axis, 19.65% of total variance explained, separate sites according to a current velocity gradient. LRD index values, describing lentic-lotic characteristics of surveyed sites, positively correlated (r = 0.698) to this axis, confirm the axis interpretation and evidence the usefullness of this index. Agricultural areas (Figure 2), Land use Index (Feld, 2004) and industrial units are significatively correlated to slower current velocities. Forested areas are correlated to faster current velocities.

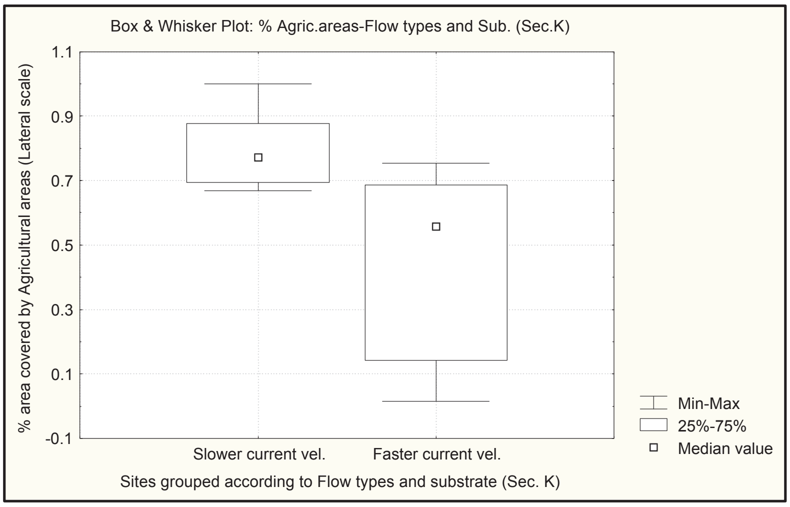


Figure 2: % area covered by Agricultural areas at intermediate spatial scale (lateral) in sites ordered according to Flow types and substrates recorded at Section K of RHS SE method.

Spot Checks

First two PCA ordination axes account for 12.12 and 11.86% of total variance of flow types and substrates data recorded at spot checks in 22 surveyed sites. They mainly separate sites according to secundary channel flow type and substrate characteristics. Sites with a lower current velocity in the secundary channel and smaller substrates in the main channel are separated from sites with secundary channels with a faster current velocity and larger substrates in the main channel. LRD index correlations with the two axes confirm their interpretation, according to current velocity gradient. Agricultural, urban and industrial land use, recorded at subcatchment/catchmentscale, are correlated to secundary channels with a lower current velocity. Forested areas, at intermediate scale (lateral) and industrial areas, at site scale (300 m), are correlated to sites with secundary channels with a faster current velocity and larger substrates in the main channel.

Hydromorphological data sets analysis evidenced as:

- Orco and Chiusella unstable river reaches can be evidenced by the presence of beaches, dunes, sand and mineral extraction sites, recorded at catchment scale, which resulted to be correlated to site scale features indicating high depositional/erosional activity (sand and gravel deposits).
- Urban land use is correlated to straight, more stable river reaches and more stable substrate structure. The main human induced alterations are channel straightening and banks reinforcing, as consequence urbanised river reaches are more straight and more stable than natural river reaches.
- Land use categories recorded at catchment/subcatchment scale may influence microscale characteristics of current velocities and substrates.

Scale	Analysis	Interpretation				Hydromorphological features		Catchment scale		Subcatchment		Lateral		300 m area along each bank		RHS			
	PCA					Feature	scale	Land use	r	Land use	r	Land use	r	Land use	r	Land use	r	Other	r
Macro/mesoscale	Deposition/Erosion	Axis 1	31,21%	Pos.	Unstable river reaches	Sand dep., SB, gravel dep.(Sec.K). MB (SC).	Sec.K, SC	Beaches, dunes, sand mineral extraction sites	0.5369 0.498			Complex cultivations	-0.4239	Broadleaf plantations (poplars) Herbaceous vegetation sparse houses	0.5966 -0.4816 -0.461	Tilled land Scrub & Shrub Orchard	0.5455 -0.5245 -0.3199		
				Neg.	Stable river reaches	VP, VS, EC (Sec.K). VB (SC).	Sec.K, SC												
		Axis 2	18,77%	Pos.	Straight river reaches	SB (Vegetated and non vegetated, Sec. K), % SC no curves.	Sec.K, SC					Industrial and commercial units Green Urban areas Broad leaved	0.4573 0.4573 -0.432	Small villages active quarriyng	0.4551 0.411			% of straight SC S bankface str.	0.6918 -0.4432
				Neg.	Curved river reaches	VP, Sand dep.and EC (Sec.K). S bankface structure (SC).	Sec.K, SC												
Mesoscale	Bars	Axis 1	31,91%	Pos.	Instable sub.structure	MB and SB (Sec. K), MB (SC): both in I and II channel.	Sec.K, SC			Sparsely vegetated areas transitional woodland scrub coniferous forest Discontinuous urban fabric agriculture with nat.vegetation Artificial surfaces	0.5466 0.511 0.5008 -0.5401 -0.5286 -0.5204	Coniferous forest non irrigated arable land Sparsely vegetated areas	0.5381 0.5231 0.4928			Orchard	-0,5515	HMS	-0,3738
				Neg.	Stable sub.structure	VB and VP (Sec.K), I and II channel VB (SC).	Sec.K, SC												
		Axis 2	24,70%	Pos.	Straight river reaches	MB and SB, vegetated and unvegetated.	Section K							Scrub and shrub	-0,4309	Orchard Tall herbs	0.5305 0.4066		
				Neg.	Curved river reaches	Point bars, vegetated and unvegetated.	Section K												
Microscale	Flows and sub.(recorded at SC)	Axis 1	12,12%	Pos.	Smaller substrates and II channel with slower current	II channel with NP as primary and RP as secundary Flow type, gr-peb substrate, Cobbles in I channel.	SC			Non irrigated arable land continuous urban Fabric industrial and commercial units	0.5962 0.5916 0.5183	Mixed forests transitional woodland scrub	-0.4706 -0.451					**LRD**	0,3396
				Neg.	Larger substrates and faster current in II channel	II channel with SM Flow type and gr-peb sub., gr-peb, boulders and cobbles in I channel.	SC												
		Axis 2	11,86%	Pos.	Faster current velocity in I and II channels	II channel with SM/RP Flow type and gr-peb/co sub., I channel with UW/RP flow type and CO as sec.substrate.	SC	Complex cultivations	-0,4236					Industrial areas	0.4705			**LRD**	-0,3524
				Neg.	II channel with no current and I channel with low current velocity	II channel with NP as sec.Flow type and co/gr-peb substrate, I channel with SM as sec. Flow type and gr-peb as sec.substrate	SC												
	Flows and sub. (recorded at Sec.K)	Axis 1	24,27%	Pos.	Natural	RP, BW, NP, Ebo, SM, CH.	Section K			Moorland	0,5391			Broadleaf plantations (poplars) Grassland	0.5318 -0.5471			U bankface str. U banktop str. S banktop str. HQA LRD HMS	0.5077 0.4839 -0.542 0.2887 -0.2513 - 0.1348
				Neg.	Artificial	RP, NP, UP.	Section K												
		Axis 2	19,65%	Pos.	Slow current velocity	Flow type: SM, RP and NP (section K nat.)	Section K	Complex cultivations Sparsely veg.areas Bare rocks Forested areas	0.6035 -0.5513 -0.5132 -0.5058	Industrial and commercial units Agricultural areas Mixed forest	0.6004 0.586 -0.6161	Agricultural areas Land use Index Forested areas glaciers	0.7074 0.7068 -0.7047 -0.5233			Rock, scree or sand dunes	-0,5128	LRD HMS HQA	0.6982 0.1778 0.1021
				Neg.	Faster current velocity, Exposed boulders.	Flow type: BW; Substrate: Exposed boulders.	Section K												

Table 2: PCA results. Axis interpretation and land use categories more correlated to ordination axis are reported for each RHS SE hydromorphological data set. Abbreviations from RHS field Survey Guide. Bars and banks: MB = midchannel bars; VB = vegetated midchannel bars; SB = side bars; VS = vegetated side bars; PB = point bars; VP = vegetated point bars; EC = eroding cliff; U = uniform; S = simple. Flow types and substrates: CO = cobbles; Ebo = exposed boulders; SM = smooth; NP = not perceptible; UW = unbroken waves; UP = upwelling; CH = chute. Calculated indexes: LRD (Buffagni et al., 2004), HMS, HQA.

2.2.7 Perspectives, Cause Effect Chain and Cause Effect Recovery chain

The preliminar results, which will be used as starting point to choose sampling sites in Orco and Chiusella catchments in Task 2, evidence possible cause-effect chains according to climatic/hydrologic/land use scenarios expected.

In the selected Nort Western Italian Alps catchments, the climate changes would lead to more frequent and intense autumn-winter floods, more frequent and more severe summer droughts and will lead to changes in catchment land-use, in particular on the floodplain. We hypothesized as possible future trends the following alternative key hypothesis:

- global change will improve morphology and biodiversity, with an increase of the extent of buffer strips and the supply of coarse woody debris, due to the withdrawn of maize intensive cultivation from the floodplain and the subsequent reforestation of this areas.
- global change will cause hydromorphological deterioration through habitat modification and losses, which will affect natural hydromorphological characteristics and the potential for channel form restoration as consequence of a more variable discharge regime and of a growing human intervenction in channel protection structures building after floods.

The demographic growth and consequently the urban development will affect larger areas which, in South european countries, where more intense droughts are expected, probably will be situated always nearer to the river channel. The urban land use, through channel straightening and banks reinforcing, directly affect hydromorphological characteristics from macro to microscale, making rivers more stable and straight. Hydromorphological features characteristic of unstable and curved river reaches, as sand deposits and point bars, could be greatly affected by human impact.

Owing to this, we consider the reduction of intervenction on fluvial morphology and the development of buffer strips in selected river reaches, as usefull management measures in our study catchments.

2.2.8 Bibliographic references

Arnell N.W., 1999. The effect of climate on hydrological regimes in Europe: a continental perspective. *Global Environmental Change*, 9: 5-23.

Brunetti M., L. Buffoni, M. Maugeri & T. Nanni, 2000. Precipitation intensity trends in northern Italy. *International Journal of Climatology*, 20: 1017-1031.

Buffagni A. & J. L. Kemp, 2002. Looking beyond the shores of the United Kingdom: addenda for the application of River Habitat Survey in Southern European rivers. *Journal of Limnology*, 61(2): 199-214.

Buffagni A., S. Erba, D. Armanini, D. De Martini & S. Somarè, 2004. Hydromorphology and the lentic-lotic character of Mediterranean rivers: River Habitat Survey and LRD descriptor. In *Ecological Classification and Lentic-Lotic Character in Mediterranean Rivers*, Quaderni, 122, CNR-ISTITUTO DI RICERCA SULLE ACQUE, ROMA, 41-63 p.

Davies M. B. & D. B. Botkin, 1985. Sensitivity of cool-temperate forest and their fossil pollen record to rapid temperature change. Quaternary research 23: 327-340.

Duce P., D. Spano, A. Motroni & S. Canu, 2003. Rischio climatico per l'agricoltura in ambiente mediterraneo. Atti Workshop "CLIMAGRI – Cambiamenti Climatici e Agricoltura", Cagliari, 16-17 gennaio 2003.

Environment Agency, 1997. *River Habitat Survey, 1997 field survey guidance manual*. Environment Agency.

Environment Agency, 2003. River Habitet Survey in Britain and Ireland - Field Survey Guidance Manual: 2003 Version. Warrington, Cheshire WA4 1HG.

Feld C., 2004. Identification and measures of hydromorphological degradation in Central European lowland streams. *Hydrobiologia*, 516: 69-90.

Frei C. & C. Schär, 1998. A precipitation climatology of the Alps from high-resolution rain-gauge observations. *International Journal of Climatology*, 18: 873-900.

Frei C., J. Hesselbjerg Christenses, M. Dequé, D. Jacob, R. G. Jones & P. L. Vidale, 2003. Daily precipitation statistics in regional climate models: evaluation and intercomparison for the European Alps. *Journal of Geophisical research*, 108 (D3), 4124, doi:10.1029/2002JD002287.

Hossell J.E., P.J.Jones, J.S. Marsh, M.L. Parry, T. Rehman & R.B. Tranter, 1996. The Likely Effect of Climate Change on Agricultural Land Use in England and Wales. *Geoforum*, 27 (2): 149-157.

Hulme M., G.J. Jenkins, X. Lu, J.R. Turnpenny, T.D. Mitchell, R.G. Jones, J. Lowe, J.M. Murphy, D. Hassell, P. Boorman, R. McDonald & S. Hill, 2002. *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

Miller C. & D. L. Urban, 1999. Forest Pattern, Fire, and Climatic Change in the Sierra Nevada. *Ecosystems*, 2: 76-87.

Podani J., 2000. Introduction to the exploration of multivariate biological data. Backhuys Publishers, Leiden.

Räisänen J., U. Hansson, A. Ullerstig, R. Döscher, L. P. Graham, C. Jones, M. Meier, P. Samuelsson & U.Willén, 2003. *GCM driven simulations of recent and future climate with the Rossby Centre coupled atmosphere – Baltic Sea regional climate model RCAO*. SWECLIM programme and EU PRUDENCE project, report number: RMK No. 101, January 2003, 61 pp.

Schmidli J., C. Schmutz, C. Frei, H. Wanner & C. Schar, 2002. Mesoscale precipitation variabilty in the region of the european Alps during the 20th century. *International Journal of Climatology,* 22: 1049-1074.

Wright J.F., R.T. Clarke, R.J.M. Gunn, J..M. Winder, N.T.Kneebone, & J. Davy-Bowker, 2003. Response of the flora and macroinvertebrate fauna of a chalk stream site to changes in management. *Freshwater Biology*, 48, 894-911.

Wright J.F., R.T.Clarke, R.J.M.Gunn, N.T. Kneebone., & J. Davy-Bowker, 2004. Impact of major changes in flow regime on the macroinvertebrate assemblages of four chalk stream sites, 1997-2001. *River Research and Applications*, 20 (7).

2.3 Vecht catchment (The nederlands)

Piet Verdonschot, Rebi Nijboer and Niels Evers (ALTERRA)

2.3.1 Scenarios

Climate

The historical and current climate data were obtained from the Dutch Royal Meteorological Institute (KNMI 2004) from the weather station 'De Bilt'. This station is situated about 150 kilometres west of the catchment but it is the only station with suitable time series of temperature and precipitation measurements. The two major climate parameters, temperature and precipitation were analysed over the last 100 years.

Minimum, average and maximum temperature all show a positive trend from 1901 to 2003 (Figure 1). But these trend lines are not significant (low R^2 values). The slope of the trend line in the maximum temperature is much lower then those for the average and minimum temperature.

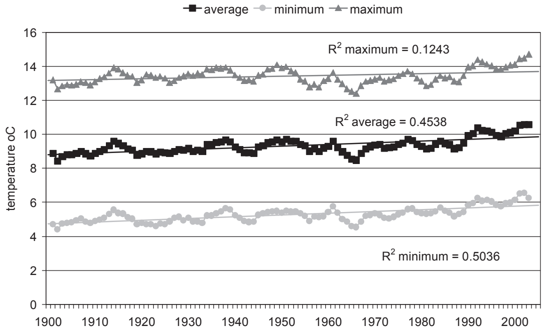


Figure 1. The minimum, average and maximum temperature from 1901 to 2003, expressed as a 5-years average.

Precipitation shows a positive trend over the last hundred years, though strongly fluctuating and not significant. Based on these data the precipitation increases with about 8.6 mm per year.

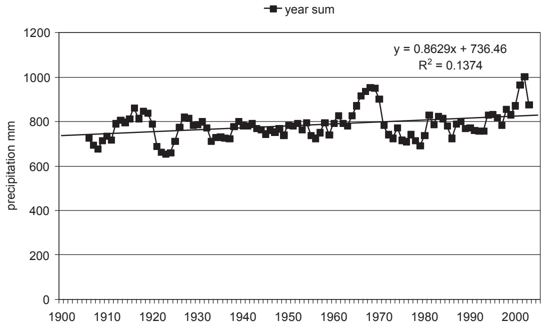


Figure 2. The daily average precipitation from 1901 to 2003, expressed as a 5-years average.

The Dutch National Research Programme commissioned the Hadley Centre for Climate Prediction and Research to provide them with a climate scenario for European weather in the period 1980-2100 (Viner and Hulme 1998, Verweij and Viner 2001). This scenario has been generated by Hadley's General Circulation Model (GCM) with a grid cell size of 3.75 degrees in longitude and 2.5 degrees in latitude. We used the data for the period 2070-2100, as these data provide the most extreme case, for the scenarios (4) of the future river Vecht catchment. These four climate scenarios were used to predict future discharge events. Therefore, the subcatchment Hollander Graven was modelled with the integrated model SIMGRO. SIMGRO is a comprehensive model of soil water, groundwater and surface water.

Discharge
Discharge data were collected from the province of Overijssel, the water board Regge & Dinkel and Alterra. Discharge data were lacking from most streams in the catchment. Therefore, five representative but different stream types with data available were selected (Table 3). However, none of these data sets was complete.

Table 3. Availability of discharge data.

		discharge data	
stream	**stream type**	**from**	**until**
Vecht	river	1970	1998
Regge (downstream)	smaller river	1957	2003
Regge (upstream)	lower course	1974/1990	1983/2003
Dinkel (downstream)	small river	1976	2003
Dinkel (upstream)	lower course	1980	2003
Radewijkerbeek	middle course	1980	1993
Springendalse beek	upper course	1993	2003

In general, discharge did not change much over the last 30 years (Figure 3).

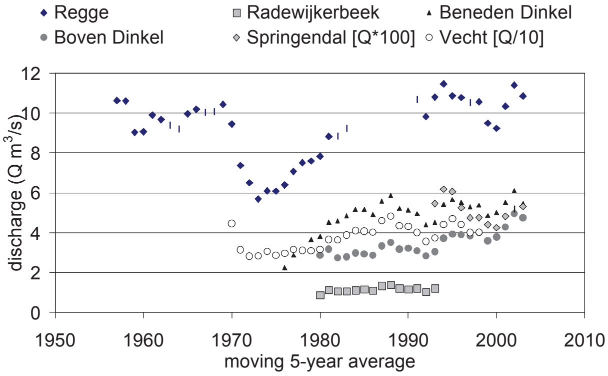


Figure 3. Discharge (moving 5-years average of daily discharge) pattern of different stream types in the Vecht catchment.

With the climate predictions of the period 2070-2100 applied to the hydrologichal model SIMGRO a slight change in hydrological extremes can be seen (Figure 4).

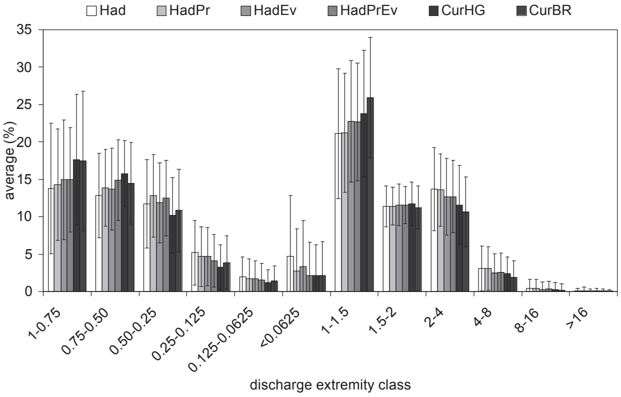


Figure 4. Discharge extremity classes for the year 2100. The average (%) of daily discharge classes calculated for 423 stream sections in the sub-catchment of the Vecht: Hollander Graven (Cur = current climate, Had = Hadley scenario, Pr = corrected for precipitation, Ev = corrected for evapotranspiration).

Following the predictions using the climate scenarios, discharge will become somewhat more dynamic, especially the classes 2-4 and 0.5-0.25 times median discharge increase while the more constant classes decrease.

Land-use

Four historical time periods were selected to establish the major land-use categories. Data from the first period (around 1900) were extracted from the digitalised map of 'Historical Land-use in The Netherlands' (HGN; Runhaar et al. 2003). The program ArcView was used to extract the information. The other periods were counted by hand, except for the current land-use cover which was xtracted from digitalised maps (Top 10 Vector map).

For the analysis of land-use, the following categories were distinguished:

√ hay- and grassland
√ field, arable, agricultural and bare land
√ heather and peat-moor
√ forest (deciduous and coniferous)
√ road and urban
√ others, including surface waters

For each category the surface area was calculated for the sub-catchments of the river Vecht. Three major changes took place over the last 100 years in the Vecht catchment. The area of heather and moorland peat dramatically decreased while the agricultural, urban and other land-use categories increased (Figure 5). The percentage of forest was stable over the whole period.

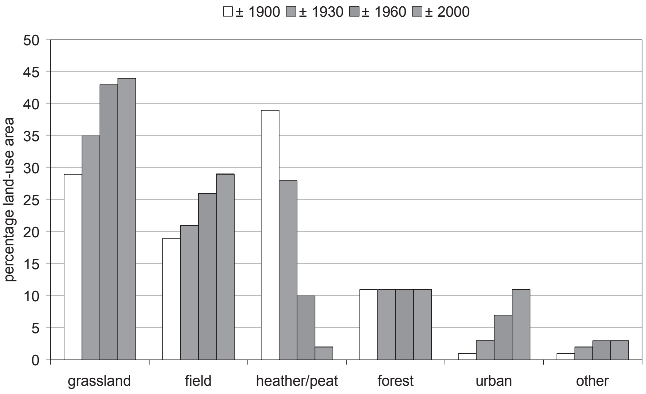


Figure 5. Percentage of land-use in the Dutch part of the Vecht catchment in four periods over the last 100 years.

The future land-use is difficult to predict. It is assumed that a withdrawal of agricultural activities from the floodplain can be expected. Furthermore, agricultural intensity will decrease in the catchment, at least with respect to nutrient input.

2.3.3 Collected data

Stream morphology

Stream morphology is expressed by three parameters:

√ Sinuosity
√ Transversal profile shape
√ Presence of weirs

Meandering is expressed as sinuosity. Sinuosity is defined as the ratio between the length of a stream stretch and the length of the stream valley. As for most streams only the somewhat larger sized parts were clearly represented on maps, especially the older ones, this parameter was calculated only for those. Hereby, again a selection was made of those streams most representative per sub-catchment.

For the periods around 1900 and 1930 digitalised topographical maps were used ('Bonne' maps 1:25000). With the program ArcView 3.3 the sinuosity was calculated. The topographical maps from around 1960 were manually elaborated. The recent topographical maps were again elaborated with the program ArcView 3.3 (Top 10 Vector map).

Sinuosity is also expressed as meandering category. The definitions are:

straight = sinuosity is 1.00-1.15
slightly meandering = sinuosity is 1.15-1.30
meandering = sinuosity is 1.30-1.50
strongly meandering = sinuosity is > 1.50

In general, the morphological features of the streams in the Vecht catchment show a degradation over the last hundred years (Table 4). The total stream length was shortened by about 20%. Forty percent of the connected side-arms got lost and the number of oxbows increased around 1930 due to straightening of the major streams but decreased during the last period with about 38%.

These tendencies are representative for the whole catchment. Some exceptions are the straight streams in the Regge East catchment, that were already present at the beginning of the twentieth century and the nowadays still slightly meandering Dinkel. In the other sub-catchments the total stream length was shortened by about 25%.

Table 4. General morphological features of the Vecht catchment.

	period	longitudinal profile type	total valley length (km)	total stream length (km)	number of connected side-arms	number of oxbow lakes
total Vecht catchment	± 1900	meandering	230.9	317.7	22.0	25.0
	± 1930	slightly meandering	229.8	272.1	55.0	63.0
	± 1960	slightly meandering	232.3	268.1	33.0	39.0
	± 2000	straight	231.6	257.8	13.0	39.0

2.3.6 Perspectives, Cause Effect Chain and Cause Effect Recovery chain

Perspectives for the Vecht catchment.

Workpackage 2 considered two hypothetical Cause Effect Chains that reflect the interactions between climate change and river hydromorphology through land use/discharge alterations: I. hydromorphological deterioration through intensification of land-use or through a more variable discharge regime that results in habitat modification and losses; or, alternatively, II. a significant improvement for the withdrawn of human disturbances from the floodplain due to more frequent flood events or as a result of floods that generate a near-natural habitat structure, etc.

A large part of the catchment is under agricultural use. Through the recent changes in agricultural policies as well as water management both hypotheses can become true in the Vecht catchment. As agricultural policies leads to a withdrawn of farmers from less usable agriculrural soils or areas these areas become available and will be often bought by nature conservation organisations. Together with water authorities stream restoration projects will lead to a significant improvement of the floodplain due to more frequent flood events that generate a near-natural habitat structure under an restored near natural stream morphology. On the other hand other streams in agricultural and urban areas will suffer from a more variable discharge regime that results in habitat modification and biodiversity losses.

Major restoration measures that will be potentially successful in the catchment of the river Vecht are re-meandering on large scale or over a large strecht (an exampled will be studie over the next four years in the Geeserstroom, a complete upper- and middle course of a lowland stream that will be reconstructed next year) together with a change of land-use (a balanced fertilisation and a reduced or removed drainage).

2.3.7 Conclusions

In conclusions two questions were answered:

1. What is the relation between climate - land-use - discharge - morphology in the Vecht catchment over the last 100 years?

- √ hydrological change is documented only from 1950 on, and showed little change in dynamics after the seventies
- √ morphological change took place in three phases (1900, 1930, 1960) and was not related to climate but to land-use
- √ most changes took place in the first decennia of the 20th century

2. What is the effect of changes in discharge regime (caused by climate change) on the stream ecosystems?

- √ discharge will become somewhat more dynamic which will affect both stream morphology and stream ecology

2.3.8 References

KNMI, 2004 [website]. Daggevens van het weer in Nederland. Viewed on march 15, 2004 at http://www.knmi.nl/product/.

Runhaar J., P.C. Jansen, H. Timmermans, F.P. Sival & W.C. Knol, 2003. Historische waterhuishouding en historisch grondgebruik in het waterschap Regge en Dinkel. Alterra-rapport 801.

Verweij, W. & D. Viner, 2001. Description of the default climate scenario for impact projects in NRP-II. Dutch National Programme on Global Air Pollution and Climate Change. Report no. 410 200 058. RIVM, Bilthoven.

Viner, D. & M. Hulme, 1998. The climate impacts LINK project: Applying results from the Hadley Centre's climate change experiments for climate change impacts assessments. CRU, UEA, Norwich, United Kingdom.

2.4 Dinkel, Lahn, Eder catchments (Germany)

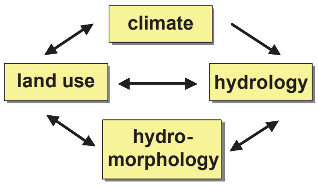
Jochem Kail, Sonja Jähnig and Daniel Hering (UDE)

Relation between land-use and hydromorphology in Central European streams: general description of the study catchments (Dinkel, Lahn, Eder, Germany)

2.4.1 Introduction

The study design is based on the two following general considerations:

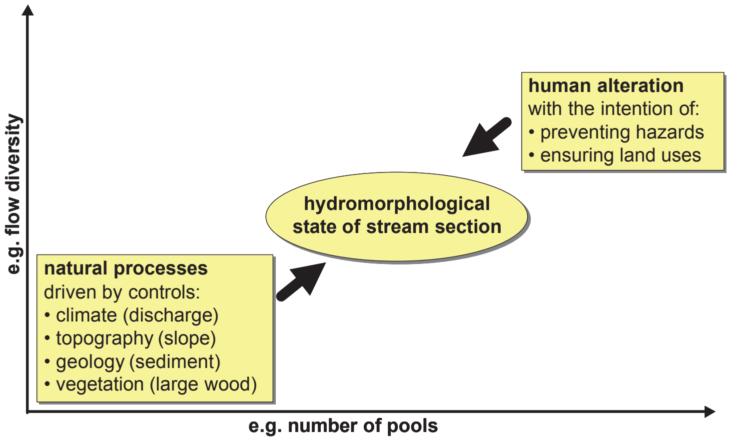
First: The relation between land-use and hydromorphology is part of the cause-effect "net" shown in the figure below.



It is hypothesized that the main natural factors influencing land use on the floodplain are climate, hydrology and hydromorphology.

Second: The hydromorphological state can be described by different hydromorphological parameters. This state depends on two forces, which act on the stream (see figure below). First, the natural processes, which are driven by controls like discharge, slope, sediment or large wood. If these processes are not disturbed by man, the hydromorphological state reaches an equilibrium state, which is stream-type specific. Second, the human impact, which intends to prevent hazards and to ensure the land-uses on the adjacent floodplain. If the natural hydromorphological state or the natural processes restrict these land-uses, man either alters the natural state / processes or changes the land-uses.

The present non-natural state of the streams can be considered to be an equilibrium state, which results from the magnitude of these two forces (see figure below).



If, for example, the pressure of the natural processes increases, because peak flows increase due to climate change, man must either increase the "land-use pressure" (e.g.; build higher embankments, build more bank-revetments to prevent lateral migration of the channel) or change the land-use. If land-use pressure is decreased, a more natural hydromorphological state will develop (new equilibrium state), which results in a change of the parameters used to describe the hydromorphological state.

Based on these considerations it is hypothesized that (a) the equilibrium hydromorphological state depends on the adjacent land uses, because the human impact depends on the economic value of the land uses; (b) climate change influences the equilibrium state, because changes in discharge will change the natural processes (natural channel dynamics).

To investigate the influence of climate change on hydromorphology, which in turn influences biota, a three step study design is used. First, the influence of land use on hydromorphology is investigated. Results of this analysis show, if and how hydromorphology depends on the land uses on the adjacent floodplains. Second, possible land use changes, which will probably occur because of the change of the natural factors influencing land use (climate, hydrology, hydromorphology) are described in different land use scenarios. Third, using the relation between land use and hydromorphology quantified in the first step, changes of hydromorphology due to the land use changes described by the different scenarios is assessed. Of course, this is a simplification of the cause-effect net shown in the first figure. Due to the fact that the precipitation and temperature data of the climate scenario were not delivered up to now, only the work on the first step has been finished yet.

2.4.2 Scenarios: Climate / discharge / hydromorphology / land-use scenarios

The climate scenario will be provided by WP 1. For all catchments, data on precipitation and temperature will be generated for the time period 2070-2100.

These climate data will be used to calculate discharge data for the Lahn and Eder catchments. This will be done using an existing rainfall / runoff model, which was developed by the Leichtweiß-Institute of Hydraulic Engineering at the Braunschweig University of Technology. Unfortunately, there is no such rainfall / runoff model available for the Dinkel catchment.

Numerous hydraulic geometry equations are described in literature, which can be used to calculate certain cross-section parameters like bankfull width or mean depth on basis of discharge data (see summary in Knighton (1998), p. 173, Harnischmacher (2002), Bogaart et al. (2003)). Channel pattern can be predicted using comparable empirical equations (see summary in Bridge (2003) p. 153-162, van den Berg (1995), Bledsoe and Watson (2001)). Present discharge data and future discharges calculated by the rainfall / runoff model will be used to predict the present and future natural state of the streams in the study catchment on basis of these empirical equations. These data will be used to assess, if the pressure exerted on the adjacent land use by the natural channel dynamics increases or decreases. If, for example, the predicted future channel width of a stream section is larger compared to the predicted present state, the “pressure” of natural channel dynamics and the costs to ensure intensive land uses adjacent to the stream will increase. It is not clear yet, if this can be done only for single case studies (single stream reaches) or the whole catchment.

The information on climate, discharge, and hydromorphological change will be used to develop land-use scenarios. We are not aware of any reports or papers on land use changes due to climate change for the study catchments.

2.4.3 Collected data

Climate / discharge data

There are to analogues sources for climate date: (a) a climatological atlas of Northrhine-Westphalia (1989), which contains monthly means of precipitation for each month, calculated from data from 1951-1980; scale 1:1.000.000, and (b) the journal "Weather Report", which has been published since 1953, displaying daily precipitation data and monthly means of the station net of the “Deutscher Wetterdienst” (German Meterological Organisation). No digital data are available.

Discharge data are available for several gauging sites, which are distributed throughout the catchments: 4 in the Eder catchment (Eder: Beddelhausen, Auhammer, Schmittlotheim; Orke: Dalwigksthal), 2 in the Lahn catchment (Biedenkopf, Sarnau), and 2 in the Dinkel / Vechte catchment. Discharge is generally measured daily by automatic devices. These data are available as daily averages for time-periods of at least 10 years.

Hydromorphological data

The study is based on a large hydromorphological data set that has been compiled from regional authorities in Northrhine-Westphalia and Hesse. Since the mid-1990’s, hydromorphological surveys have been conducted in the two federal states. Slightly different methods have been applied in the surveys performed by the two federal states, but they do essentially correspond to the field survey method of the “Länderarbeitsgemeinschaft Wasser” (LAWA) briefly described by Raven et al. (2002).

The mapping method, which was used in the federal state of Northrhine-Westphalia is described in a textbook, which can be downloaded from the web: **http://www.lua.nrw.de/veroeffentlichungen/sondersam/handbnaturn/handbnaturn_start.htm**.

The objective of the mapping was to assess the hydromorphological state, not to exactly map all channel-features (no “inventory”) The terms and classification of the channel-features used are only partly based on a sound scientific basis, and the terms and classification of some channel-features do not correspond to the ones generally used in fluvial science (e.g., fluvial morphology).

The results of the LAWA hydromorphological survey method can be analysed and interpreted at different levels of resolution: the 25 attributes recorded are grouped into six “main categories”, further aggregated into three “higher categories” (stream bed, stream bank, floodplain) and finally into a single value.

All attributes are recorded along 100 m channel segments and compared to a reference condition, which is defined as the “potential natural state” of the stream (the condition that would result naturally without further human intrusion). The assessment results of the individual attributes are used to calculate a result for each of the six “main categories”. These results are finally gauged by the expert (surveyor) in relation to the presumed reference condition. Possible results range from unchanged (only minor deviations from the reference condition, class 1) to heavily degraded (class 7).

For the statistical analysis, 17 out of the 25 parameters were selected, which show a gradient so the stream sections can be classified on an ordinal scale. Only these 17 parameters are described here. Data on these 17 parameters are available for about 16,500 sections (data sets) in the study catchments.

a.) planform / sinuosity

Planform is classified into 7 classes ranging from heavily meandering to straightened using the deviation of the stream axis from the valley axis (maximum angle between the stream axis and the valley axis). Unfortunately, definitions of different planforms are not based on the ratio "channel length / valley axis length" as it is normally done in fluvial morphology.

b.) bars

The following bars are summarized here: channel side bars, point bars, channel junction bars, mid-channel bars, diagonal bars (according to bar classification of Church (1992)). Note that the mapping method is not based on any bar classification used in international literature (e.g., Church (1992)), but the short descriptions and photos given in the textbook of the mapping method used in Northrhine-Westphalia indicate that the bars listed above were mapped.

The number and extent of the bars within the stream section 100 m in length were classified as: (a) many compared to the potential natural state, (b) some compared to the potential natural state, (c) two bars, (d) one bar, (e) only bars of small extent, (f) none. Therefore, there is no information on the exact number of bars, if there are more than two. Moreover, there’s no information on the exact kind of bars present within the stream section (number of all types of bars are added up).

c.) features indicating natural channel dynamics

Channel features, which indicate natural channel dynamics are summarized here: large wood, wood accumulations, islands, multiple-channels, channel-widening, channel-narrowing. The number and extent of the channel-features within the stream section 100 m in length were classified using the same classes as for the number of bars. Therefore, there’s no information on the exact number of channel-features, if there are more than two, and no information on the exact kind present.

d.) riffles and steps

Riffles of riffle-pool sequences and steps of step-pool sequences should have been counted here (for definitions of riffles and steps, which corresponds to what should have been mapped here, see for example Knighton (1998), p. 193 ff and 201 ff). However, it is not sure that all surveyors did have a clear idea what riffles and steps are. Some of them probably did also count large diagonal bars and perhaps mid-channel bars. Therefore, the results are probably not comparable to other surveys, where trained fluvial morphologists did map the streams.

The number and extent of riffles and steps within the stream section 100 m in length were classified using the same classes as for the number of bars. Therefore, there is no information on the exact number of channel-features, if there are more than two, and no information on the exact kind present. But steps only occur in specific stream types like steep headwater streams. Therefore, it is possible to distinguish between these two kinds of features.

e.) channel-bed features

The following channel bed features are summarized here (note that riffles are mapped separately): scour pools (fluvial pools, plunge pools, underflow pools, deflector pools according to Robison and Beschta (1990b), confluence pools according to Overton et al. (1993), backwater pools, lateral scour pools, trench pools, excluding dammed pools according to Bisson et al. (1982, cited in Beschta and Platts (1986) and Frisell et al. (1986)), rapids, cascades, glides (according to Church (1992)), secondary channel pools (according to Flosi et al. (1998)), large areas of the channel-bed covered with roots of riparian vegetation or naturally occuring macrophytes. Note that the mapping method is not based on any classification of channel-bed features used in international literature (e.g., Church (1992)). But the short descriptions and photos given in the textbook of the mapping method for Northrhine-Westphalia indicate that the channel-bed features listed above were mapped.

The number and extent of these channel-bed features within the stream section 100 m in length were classified using the same classes as for the number of bars. Therefore, there is no information on the exact number of channel-features, if there are more than two, and no information on the exact kind present.

f.) flow diversity, depth variability, substrate diversity, cross-section width variability

Different types of flow, depth, substrate, and cross-section width variability are defined and illustrated by photos in the textbook of the mapping method used in Northrhine-Westphalia.

The state of the stream section in respect to the four attributes was classified as: (a) very high (> three flow conditions / depth categories / substrate types / width categories, three of them of large extent), (b) high (three flow conditions / depth categories / substrate types / width categories, two of them of large extent), (c) medium (three flow conditions / depth categories / substrate types / width categories, two of them of low extent), (d) low (two flow conditions / depth categories / substrate types / width categories, one of them of low extent), or (e) very low (one flow condition / depth category / substrate type / width category).

Therefore, there's no information on the specific types (flow conditions, depth categories, substrate types, width categories) present in the stream section.

g.) cross-section depth (depth : width)

The depth to width ratio was used to describe cross-section depth and the different depth classes are additionally illustrated in the textbook by photos. The following depth classes (depth : width) were used: (a) very deeply entrenched (>1:3), (b) deeply entrenched (1:3 to 1:4), (c) entrenched (1:4 to 1:6), (d) shallow (1:6 to 1.10), (e) very shallow (<1:10).

h.) culverts

The presence and length of culverts was mapped. In addition it was recorded, if natural sediment is present on the stream bed in the culvert. This attribute was classified on an ordinal scale within the scope of the analysis: (a) no culverts present, (b) length of culverts < 5% of section length, (c) length of culverts 5-20% of section length, (d) length of culverts 20-50% of section length, (e) length of culverts >50% of section length.

i.) artificial impoundments

Artificial impoundments caused by dams or weirs were mapped according to the reduction of flow velocity compared to the free flowing sections. This attribute was classified on an ordinal scale within the scope of the analysis: (a) none, (b) reduced flow-velocity, but not less than 50% compared to free flowing section, (c) flow-velocity less than 50% compared to free flowing section, (d) no apparent flow-velocity at mean flow.

j.) bed-fixation

The type and extent of bed-fixation was mapped and classified on an ordinal scale within the scope of the analysis: (a) no bed fixation, (b) bed fixation (stone riprap) 10-50% of section length, (c) bed fixation (concrete with sediment on top) 10-50% of section length, (d) bed fixation (concrete without sediment on top) 10-50% of section length, (e) bed fixation (riprap or concrete) >50% of section length.

k.) cross-section form

Seven different cross-section forms were mapped, which were classified on an ordinal scale within the scope of the analysis: (a) natural cross-section, (b) near-natural cross-section, (c) unstable eroding cross-section, (d) derelict trapezoidal or rectangular cross-section, (e) deeply entrenched cross-section, (f) trapezoidal cross-section (g) rectangular cross-section.

l.) woody riparian vegetation

Six different types of woody riparian vegetation were distinguished. These types of woody riparian vegetation were classified on an ordinal scale within the scope of the analysis: (a) natural: native forest or none-woody native riparian vegetation, (b) near-natural: gallery of native tree species, partly native forest or gallery of native tree species, native single-trees / shrubs, (c) none-native: none-native forest, gallery or single trees / shrubs, (d) none because of erosion, bank-revetment or embankment.

m.) none-woody riparian vegetation

Six different types of none-woody riparian vegetation were distinguished. These types of woody riparian vegetation were classified on an ordinal scale within the scope of the analysis. Note that for all stream types investigated, woody vegetation is the natural type of riparian vegetation: (a) natural: no none-woody vegetation, (b) near-natural: cane, perennial herbs, (c) none-natural: pasture, (d) none: none because of erosion, bank-revetment or embankment.

n.) bank-revetment

The type and extent of bank-revetment was mapped. This attribute was classified on an ordinal scale within the scope of the analysis: (a) no bank-revetment, (b) gallery of trees 10-50% of section length, (c) stone riprap, wooden bank-revetment, sod, unauthorized revetment like building rubble 10-50% of section length, (d) cobbled pavement 10-50% of section length, (e) concrete 10-50% of section length, (f) all methods of bank revetment excluding concrete >50% of section length, (g) concrete >50% of section length.

Land use data

The so-called “ATKIS” land-use data were used. These data were mapped by regional authorities on topographic maps with a scale 1:5000. The data consist of areal (polygons) and line data (e.g., roads, streams). A total of 192 different land-use categories were distinguished. These categories can be ordered hierarchically and were aggregated to eight areal categories and two line categories within the scope of the analysis. The objective was to distinguish between land-use categories, which differ in the magnitude of the land-use pressure “exerted” on the stream sections (see introduction for description of general concept). Moreover, it is necessary to minimise the number of land-use categories to allow for multivariate statistical analysis and to ease interpretation of the results.

The following categories were used: Areal: (1) urban area, high-density, (2) urban area, low-density, (3) traffic infrastructure, (4) intensive agriculture, (5) extensive agriculture, (6) woody vegetation, (7) none-woody natural and near-natural vegetation, (8) other. Linear: (1) roads, (2) dirt roads.

It is hypothesized that the land-use near the channel is more influential on the hydromorphological state of the stream compared to land-use far away from the stream section. Therefore, three different “spheres of influence” were distinguished: (1) the near channel area (area directly adjacent to the stream section, width of this buffer depends on stream size), (2) the valley bottom (whole valley bottom adjacent to the section, in general wider than the floodplain; the real floodplain can hardly be delineated correctly using standard GIS data), and (3) adjacent sections (near channel area of sections up- and downstream, number of sections considered depends on stream size).

a.) demarcation of valley bottom segments

The valley bottom was digitized by hand in ArcView using topographic maps, contour lines, and the extent of soil-types that occur on the valley bottom (e.g., gley). Streets directly adjacent to the valley bottom were included. Inaccurate position of borders of soil types / geology on small scale maps caused by generalization allowed the use of data on soil and geology only for larger streams and rivers.

The valley axis of the valley bottom was digitized by hand in ArcView, and the valley bottom was cut into valley segments perpendicular to the valley axis at the start / endpoints of the 100 m stream sections of the hydromorphological survey. The valley bottom was cut perpendicular to the valley axis, because problems occur if the valley bottom is cut perpendicular to the stream axis which is curved or meandering.

b.) demarcation of near-channel area segments:

To determine the near-channel area, the channel network was buffered using different buffer width for different stream sizes. The width of the buffer on each side of the channel was set to two times the bankfull channel width (w_{bf}). Buffer width (b_w) was calculated:

$b_w = w_{bf}$ + left buffer ($2* w_{bf}$) + right buffer ($2* w_{bf}$)

Buffer width for streams with $w_{bf} < 1$ m was set to 10 m.

Similar to the valley bottom, the buffer area was cut into buffer segments perpendicular to the valley axis at the start / endpoints of the 100 m stream sections of the hydromorphological survey.

c.) demarcation of adjacent sections:
The number of sections up- and downstream, which were considered to be "adjacent" to the section investigated differed according to stream size.

number of near-channel area sections considered in dependence on stream size (bankfull channel width):

bankfull channel width	number of sections considered
streams <1-5m	1
streams 5-10m	2
streams >10m	3
rivers (approximately >20m)	4

The percentage-area covered by the 8 areal land-use categories (%) and the length of the linear features of the 2 linear categories related to section area (m/m^2) was calculated for the three "spheres of influence". This resulted in 30 values for each of the 16,500 stream sections.

2.4.4 Data analysis

Each of the 17 hydromorphological parameters, which were classified on an ordinal scale was "stretched" to a scale ranging from 1 to 7 ($x_{new} = (7/n_{class}) * x$, with n_{class} = number of ordinal classes, x = original ordinal value, x_{new} = new value fed in ordination analysis). These data were used as dependant variables in statistical analysis.

The data on the percentage-area covered by the different land-use categories in the three "spheres of influence" were arcsin-transformed (arcsin $(x)^{0.5}$) according to Podani (2000). Note that the data are automatically standardized to unit variance (to bring the means to zero and variance to one) when data are processed as environmental variables in the software CANOCO, which was used for multivariate analysis. These data were used as independent variables in statistical analysis.

The statistical analysis was performed stream-type specific for the following reason: The natural hydromorphological state and the natural processes act as pressures, which restrict the land-use on the adjacent floodplain (see introduction for description of general concept). Therefore, the human impact on a stream depends on the magnitude of this pressure (e.g., if the lateral channel migration caused by peak flows is considered to be a hazard to works adjacent to the channel, bank-revetments will be built; this depends for example on stream size, slope and bank material). The pressure is considered to be stream-type specific. Therefore, the statistical analysis was performed for different stream types (n = 9 stream types in Dinkel, Lahn and Eder catchment).

Detrended correspondence analysis (DCA) was performed for the hydromorphological data to determine the length of the gradient in the data sets. If the length of the ordination axis is <<3 standard deviations, methods with linear response models like RDA can be used, otherwise CCA should be used (Jongman et al. 1995, p. 154). The length of the gradient is <<3 for all data sets and therefore, RDA was used.

Redundancy analysis (RDA) was used to investigate the relation between the 17 hydromorphological parameters ("species data") and the 30 land-use categories ("environmental variables").

First results showed that the variance of the data set on stream hydromorphology explained by the land-use categories is not large enough to calculate / predict the hydromorphological state based on land-use data (total variance explained by first two axis is about 17-22% for the different stream types).

Therefore, RDA was mainly used to identify highly predictive single land-use categories and to identify hydromorphological parameters, which are correlated to the land-use. Beside this, RDA was used to identify artefacts, which occurred in small data sets (datasets with n < 250 stream sections, this holds true for 4 out of the 9 stream types). Moreover, two data sets of stream types, which showed very similar RDA plots were merged (stream type AB). The following four different data sets were investigated:

Table: stream types of the four different data sets, stream types AB, D, E are located in the lower-mountainous area, stream type G in the lowland.

data set	stream type(s)	number of sections (100 m length)
AB	small confined headwater streams in V-notched valleys and small headwater streams in colluvial or alluvial deposits	11094
D	mid-sized alluvial streams	2563
E	large alluvial streams and rivers	1656
G	small sandbed streams	623

Besides continuous data, *Multiple Linear Regression (MLR)* can also be applied to ordinal data, if the number of ordinal classes is ≥ 5-7(Achen 1991, Berry 1993). MLR was performed to quantify the relationship between the single hydromorphological parameters and the highly predictive land-use categories identified by the RDA. For each stream section, the ordinal score of the hydromorphological parameter was calculated using the regression equations, which resulted from the regression models. This calculated ordinal score was compared the original ordinal value. The number of sections, for which the calculated ordinal score equals the original ordinal value is used as a measure of fit of the regression models.

2.4.5 Results

RDA

The land-use most influential in the lower-mountainous area is the one on the valley bottom compared to the land-use adjacent to sections up- and downstream and the near-channel area (Fig. 1). Differences increase with stream size, which is probably due to the fact that larger streams are considered as a hazard to land-uses far away from the channel. This supports the hypothesis that the relationship between land-use and hydromorphology is stream-size specific (see section 2.4.4).

Further interpretation of the ordination results is difficult, if some of the independent variables are highly intercorrelated. This holds true for many land-use categories in the four data sets. To simplify the interpretation of the complex data sets, the number of variables (land-use categories) was reduced according to the following criteria:

- The total variance of the hydromorphological data explained is maximised.
- The variance inflation factor (VIF), which is a measure for the co-correlation between variables, is less than 5 for all variables included in the RDA (as a rule of thumb, values > 10 are considered to indicate a severe problem with intercorrelated variables, which is unlikely to occur, if VIF < 5).
- Inclusion of land-use categories, which will be considered in the scenarios (if possible).
- Inclusion of land-use categories of one single sphere of influence, if land-use categories of other spheres of influence do not markedly increase the variance explained.

For all four data sets, this resulted in RDA models, which include (1) intensive agriculture, (2) extensive agriculture, (3) woody vegetation, and (4) roads on the valley bottom. RDA models of the stream types D, E, and G additionally include the land-use category (5) “dirt road on the valley bottom”. The total variance explained for stream type G could be slightly increased using the land-use data of the near-channel area. However, the slight increase does not offset the loss of comparability between the stream types. Therefore, only the five "highly predictive" land-use categories listed above were used for further analysis (MLR).

Particular combinations of land-use categories of different spheres of influence, which theoretically consider different aspects of land-use pressure were investigated, but do not markedly increase the variance explained (e.g., combining land-use categories on the valley bottom with the land-use category "road" in the near-channel area). However, to examine this in detail, all possible combinations of land-use categories must be investigated, which is not possible because of the extremely large number of combinations.

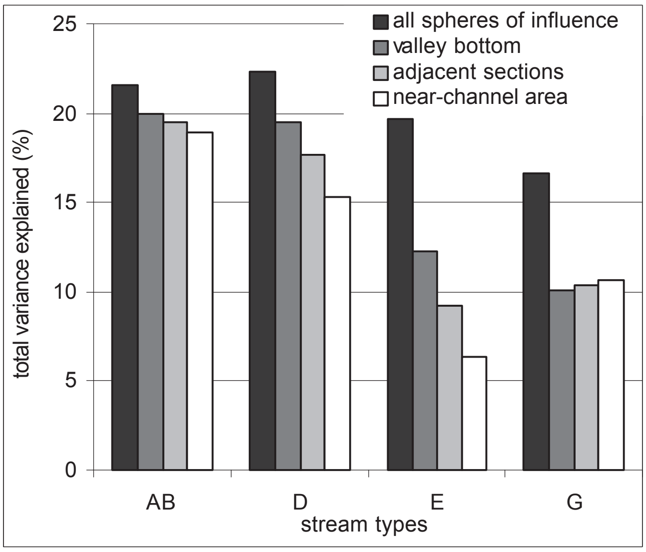


Fig. 1: Total variance of hydromorphological data explained by the different spheres of influence (all eight land-use categories included in the RDA).

The results of the RDA include information about the variance of single hydromorphological parameters explained by the combination of the five land-use categories listed above (CANOCO log file). Hydromorphological parameters, which are best correlated to these land-use categories were selected for further analysis. For these hydromorphological parameters, the percentage variance explained ranges from 20% to 33%.

MLR

For each of the hydromorphological parameters listed in the following table, MLR was performed using the highly predictive land-use categories identified by the RDA as independent variables.

The percentage of sections, for which the calculated ordinal score equals the original ordinal value ranges from about 13% to 52%. This measure of fit of the regression model seems too low to really predict / calculate the hydromorphological state based on land-use data. But it potentially can be increased by decreasing the number of ordinal classes used to classify the hydromorphological parameter. However, if the number of ordinal classes is reduced, only a drastic land-use change will lead to a re-classification of the stream section and to a detectable effect on hydromorphology, which will change the results of the scenarios. As long as the land-use scenarios are not defined, it hardly can be decided, if these regression results can be used to quantify the effect of land-use change on stream hydromorphology. At least, the results can be used to qualitatively describe the direction of change and to predict the future hydromorphological state in a semi-quantitative way for some hydromorphological parameters.

Table: Percentage of sections, for which the calculated ordinal score (calculation based on the regression equation) equals the original ordinal value.

data set	hydromorphological parameter	percentage variance of hydromorphological parameter explained (%)	percentage of sections calculated ordinal score equals original value (%)	number of ordinal classes
AB	planform / sinuosity	33.3	22.8	7
	cross-section form	32.0	34.7	7
	riffles and steps	25.5	22.8	6
	cross-section width variability	23.0	46.8	5
	features indicating natural channel dynamics	21.1	21.6	6
D	bank revetment	28.7	12.7	7
	cross-section form	25.5	49.1	7
	channel-bed features	24.6	23.5	6
	riffles and steps	21.5	24.8	6
	cross-section width variability	20.2	48.9	5
	substrate diversity	19.9	52.4	5
E	cross-section depth	26.8	42.1	5
	substrate diversity	25.2	36.9	5
	channel-bed features	22.0	28.0	6

2.4.8 Literature cited

Achen C. H., 1991. A polychotomous linear probability model. Political Methodology Society, Berkley, USA.

Berry W. D., 1993. Understanding regression assumptions. Quantitative Applications in the Social Sciences, No. 92, Sage Publications, Thousand Oaks, USA.

Beschta R. L. & W. S. Platts, 1986. Morphological features of small streams: significance and function. Water Resource Bulletin (22), 369-379.

Bledsoe B. P. & C. C. Watson, 2001. Logistic analysis of channel pattern thresholds: meandering, braiding, and incising. Geomorphology (38), 281-300.

Bogaart P. W., R. T. Van Balen, C. Kasse & J. Vandenberghe, 2003. Process-based modelling of fluvial system response to rapid climate change - I: model formulation and generic applications. Quaternary Science Reviews (22), 2077-2095.

Bridge J. S. 2003. Rivers and floodplains: forms, processes, and sedimentary record. Blackwell Science, Oxford, 491.

Church M., 1992. Channel morphology and typology. in: P. Calow, G. E. Petts. Rivers Handbook - Hydrological and ecological principles. Blackwell Science, Oxford, 126-143.

Flosi G., S. Downie, J. Hopelain, M. C. R. Bird & B. Collins, 1998. California salmonid stream habitat restoration manual. California Department of Fish and Game, Inland Fisheries Division, http://www.dfg.ca.gov/nafwb/manual.html, 495.

Frissell C. A., Liss, W. J., Warren, C. E., Hurley, M. D. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management (10), 199-214.

Harnischmacher S., 2002. Fluvialmorphologische Untersuchungen an kleinen, naturnahen Fließgewässern. PhD-thesis Geographisches Institut Ruhr-Universität Bochum,Bochum, 304.

Jongman R. H. G., C. J. F. ter Braak & O. F. R. van Tongeren, 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge.

Knighton D., 1998. Fluvial forms and processes. Oxford University Press, New York, 383.

Overton C. K., M. A. Radko, R. L. Nelson, 1993. Fish habitat conditions: Using the Northern/Intermountain Regions' Inventory Procedures for Detecting Fish Habitat Conditions: Using the Northern/Intermountain Regions' Inventory Procedures for detecting differences on two differently managed watershed. United States Department of Agriculture, Forest Service Intermountain Research Station, General Technical Report INT-GTR-300 .

Podani J., 2000. Introduction to the exploration of multivariate biological data. Backhuys Publishers, Leiden.

Raven P. J., N. T. H. Homes, P. Charrier, F. H. Dawson, M. Naura & P. J. Boon, 2002. Towards a harmonized approach for hydromorpological assessment of rivers in Europe: a qualitative comparison of three survey methods. Aquatic Conservation: Marine and Freshwater Ecosystems (12), 405-424.

Robison E. G. & R. L. Beschta, 1990b. Coarse woody debris and channel morphology interactions for undisturbed streams in Southeast Alaska, U.S.A.. Earth Surface Processes and Landforms (15), 149-156.

van den Berg J. H., 1995. Prediction of alluvial channel pattern of perennial rivers. Geomorphology (12), 259-279.

2.5 River Waldaist (Austria)

Thomas Ofenböck (BOKU)

2.5.1 General characteristics

The River Waldaist takes some kind of special position within WP2. It can be classified neither as a braided mountain river nor as a meandering lowland river which are investigated within WP 2 Task 4 or WP 2 Task 5 respectively.
Its main stressor is siltation caused by special land-use (intense *Picea abies*-crops) in the catchment, which degrades the instream habitat-structures considerably. The huge input of silty bedloads out of drainage-canals create hostile conditions for several aquatic invertebrates which can serve as indicators for the targeted impact (like *Margaratifera margaratifera*). Regarding other hydromorphological features River Waldaist is in a near natural situation. Thus the main factor to be analysed within WP2 Subtask 1.1. is the amount of silty bedloads in correlation with the land cover of coniferous forests and their drainage. The study focuses on that.

Geography and Geology
The catchment of the River Waldaist is situated in the eastern Muehlviertel in Upper Austria. It is part of the Moldanubikum of the Bohemian Massif which forms a continental watershed. To the north the catchments of Maltsch and Lainsitz discharge via Moldava and Elbe into the North Sea. The Aist as well as the neighbouring catchments of Gusen, Naarn and Kamp are part of the Danube catchment which discharges into the Black Sea.

The River Waldaist forms together with the River Feldaist the Aist - System. It is situated in the bioregion of the Austrian Granite and Gneiss Region, which is part of the ecoregion Central Highlands. Its geology is crystalline, granite predominates. Therefore total hardness is very low (1,5 –1,7°dH) as well as and the conductivity (max 110 ìS/cm) and the water is rich in humic substances which originate from boggy soils and fens in the upper parts of the catchment area.

Climate and Hydrology
The climate in this region is a subboreal dominated climate with mean temperatures of –5°C to –3°C in january and 16°C to 19°C in july and 700 mm to 1250 mm of annual precipitation.

The source of the River Waldaist (in the upper reach called Schwarze Aist) is located at an altitude of approximately 1020 m near the village of Liebenau. Near Weitersfelden (680 m) it confluences with the River Weisse Aist. The main tributaries of the Waldaist are Reiternbach, Kasbach, Waltrasedterbach, Haiderbach, Ennsedterbach, Promenedter Bach and Stampfenbach. At an altitude of 306 m it confluences with the River Feldaist.

In total the Waldaist (Schwarze Aist) has a length of approximately 60 km and its catchment area size is about 276 km². The discharge regime is pluvio-nival with an annual maximum in march and april and a lesser maximum in december and january. Mean annual discharge is 3,05 m³/s with an annual minimum of 0.77 m³/s and a maximum of 26.9 m³/s respectively. Relative runoff within the catchment is calculated as 11.05 l/s.km². Stream order (Strahler) is 4 at the mouth.

Land use in catchment area
The population density within the catchment area is very low (31 inhabitants/km²). The intensity of agricultural land use is very low as well: the share of forested areas is about 49 %, only about 15 % is used as crop land and 30.5 % is used as grassland (see figure 1). Figure 2 shows that cropland is not relevant at all in riparian properties.

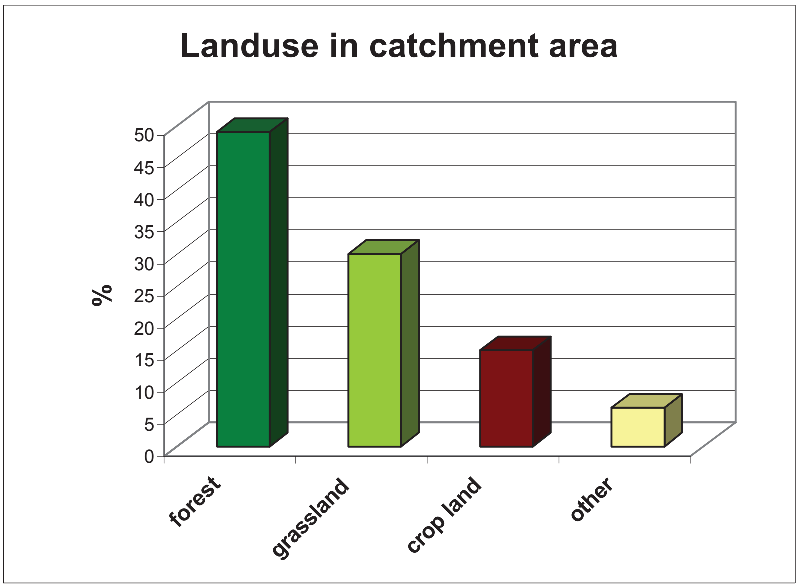


Figure 1: Landuse within the catchment area (AMT DER OBEROESTERREICHISCHEN LANDESREGIERUNG, 1996).

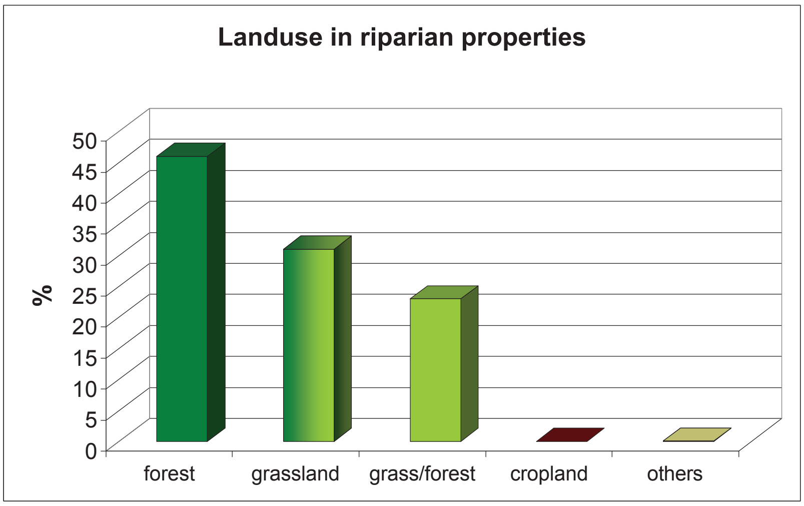


Figure 2: Landuse within riparian properties (OFENBÖCK 1997).

The stand density of productive livestock is very low as well (0,47 cattle units) (AMT DER OBEROESTERREICHISCHEN LANDESREGIERUNG, 1996). Table 1 gives an overview of land use in different municipalities.

Table 1: Land use in the catchment area (AMT DER OBERÖSTERREICHISCHEN LANDESREGIERUNG, 1996)

municipality	area		cropland	forest	grassland	cattle units
	ha	%	ha			
Bad Zell	1048	23	321	339	435	946
Gutau	3405	76	755	1353	1265	2204
Kaltenberg	897	52	221	318	375	462
Liebenau	3068	64	375	1772	825	972
Pregarten	1279	46	420	287	540	1172
Sandl	3643	62	86	2519	752	709
Schönau im Mühlkreis	1667	44	330	752	569	962
St. Leonhard bei Freistadt	3526	100	389	1937	995	1393
St. Oswald bei Freistadt	845	21	110	347	317	389
Tragwein	1689	43	421	594	704	1515
Unterweißenbach	287	6	53	147	100	128
Weitersfelden	4369	100	493	2276	971	1127
Gesamt	**25723**		**3974**	**12641**	**7848**	**11979**

15.40%	**49.10%**	**30.50%**	**0.47/ha**

In former times the land was much more intensive used for agriculture, but agricultural land use (cropland) decreases since decades and cropland and grassland were more and more substituted by forests. But, in this forests, the naturally occuring deciduous and mixed forests and fens are substituted by monocultures of coniferous trees (*Picea abies)* under suboptimal conditions, because soils are often too humid for spruces. This necessitates drainage measures which lead to increased siltation rates and a high amount of sandy bedloads within the river bed and the destruction of habitats which get covered by mobile sandy substrates.

Water Quality and pollution

Because of the low population density wastewater contamination is also of minor importance. The nutrient load is very low and the water quality shows mostly pristine conditions concerning organic pollution (OFENBÖCK 1997):

Orthophosphat: < 0,2 mg/l
P-total: 0,2 mg/l
Nitrate: < 1,5 mg/l

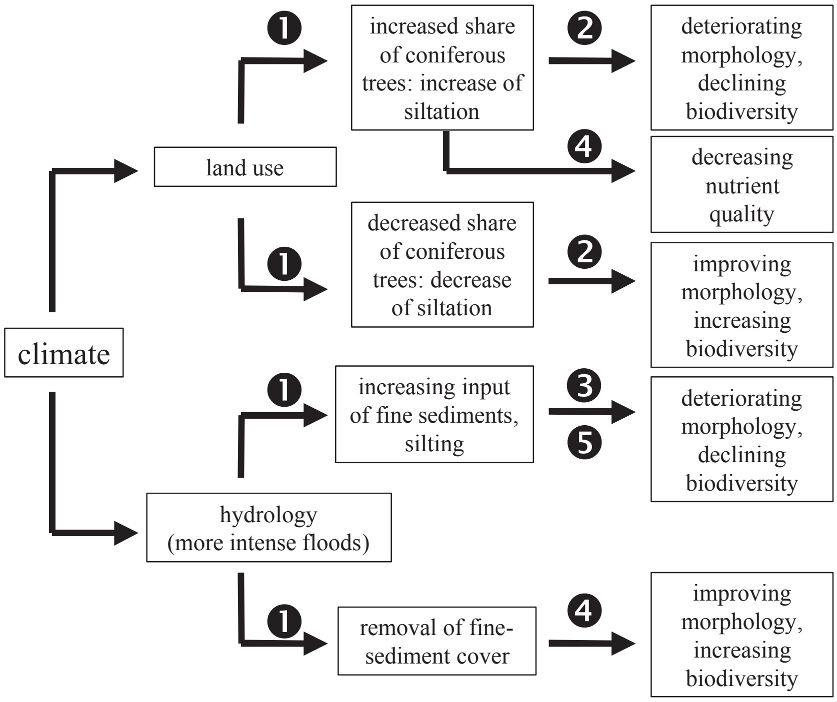
The benthic community also reflects the low impact and the saprobic index (Zelinka & Marvan) indicates saprobity class I-II.

2.5.2 Effects of climate/land use changes on hydro(morpho)logy

Expected Cause Effect Chains

Siltation rates may change through intensification or extensification of land-use, a change of landuse or through a change in the species composition of trees. A change in discharge regime (more frequent flood events or as a result of floods that generate a near-natural habitat structure) as well could have effects on habitat composition and sediment transport rates in time and space.

The hypothetical Cause Effect Chains expected is shown in figure 1.



Climate change may cause intensification/change of land use and a higher input of fine sediments into the river and a more variable discharge regime (e.g. increasing flood dynamics) that results in habitat modifications and losses. More intensive precipitation, lower temperatures and increasing flood dynamics may lead to more natural conditions (mixed forests, fens), higher temperatures may lead to changes in landuse or in the species composition of the forests (e.g. coniferous trees will have to be replaced by deciduous trees) and will lead to changes of sediment input rates and dynamics as well as changes of nutrient resource.

Changes in land use and flood dynamics will change the (fine) sediment transport dynamics and may lead to dramatic changes in habitat composition and habitat quality. Sections with (mobile) sandy deposits are hostile to several sensitive species (eg. *M. margaritifera*) and will therefore lead to a loss of habitats and biodiversity. Instream sandy deposits on other substrates also lead to changes in chemistry of the hyporheic interstices (e.g. BUDDENSIEK 1991, 1992; BUDDENSIEK et al. 1990 RICHARDS & BACON 1994).

Experiences for restoration measures are available from the River Lutter in Germany. Big parts of the catchment area were restored and some measures (e.g. sand traps) were performed to successfully reduce the input of fine substrates and more or less pristine habitat characteristics were achieved (ALTMÜLLER & DETTMER 2000).

2.5.3 Relations between land use and siltation

Materials and methods

GIS data

For the analysis of the land use within the catchment area a GIS data from Upper Austria (DORIS) was used. The GIS database contains different land use categories, but the most important ones in the investigated area are: forests, different kinds of grassland and crop land. These categories were used for the analysis (figure 2).

Figure 2: Land use in the catchment area (dark green: forest, light green: grassland).

Data on the mobility of sandy substrates

Data on the mobilisation of sandy substrates are difficult to gain and were not collected within this project up to now. But for four of the main tributaries of the River Waldaist roughly estimated data on bedload grading and mobility rates are available (KILLINGSEDER 1998). Within the study of KILLINGSEDER it is clearly demonstrated that the huge amount of mobile sandy substrates is mostly caused by drainage measures in coniferous forests. Using grain-size distribution curves for different sites, channel attributes and discharge data he calculated estimations for transport rates and mobility of bedload in relation to discharge of the tributaries Schwarze Aist (upper reach of Waldaist), Harbe Aist, Weisse Aist and Stampfenbach. Grain-size distribution curves are shown in figure 3.

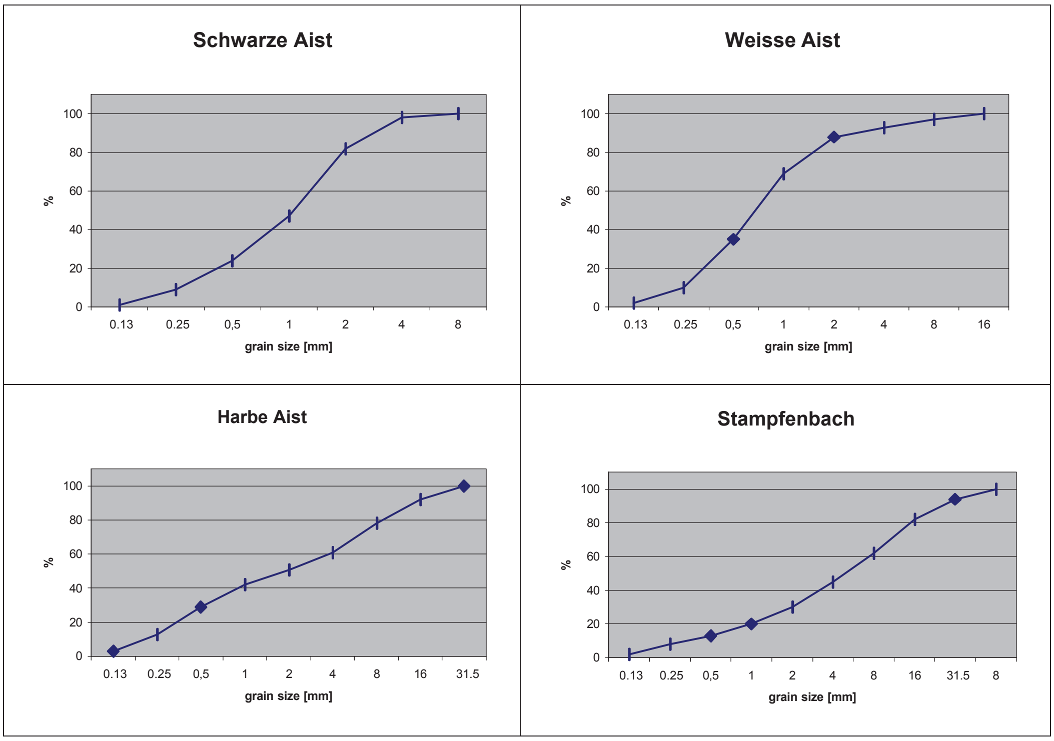


Figure 3: Grain-size distribution curves for the investigated sub catchments.

The mobility of sediments in relation to discharge was calculated using the formula of SMART & JÄGGI (1983). Low values indicate that substrates are mostly deposited in the river bed, like in the Schwarze Aist and Weisse Aist, whereas the Weisse Aist also acts as potential and considerable resource for sandy substrate during higher floods. Higher values in the tributaries Harbe Aist and Stampfenbach indicate that sandy substrates are not deposited in an amount to cause severe siltation. The results of the calculated q*-values are given in table 2:

Table 2: Transport rates in relation to discharge [%] (KILLINGSEDER 1998)

Schwarze Aist	Weisse Aist	Harbe Aist	Stampfenbach
q*= 0.65%	q*= 1.80%	q*= 5.26%	q*= 8.06%

2.5.4 Results

Figures 4-7 show the land use in the four different catchments.

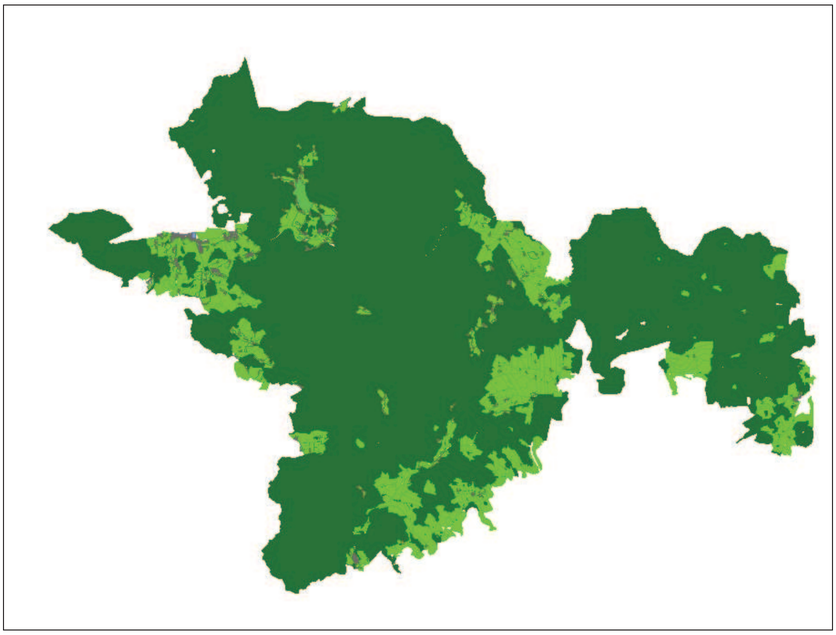


Figure 4: Land use in the upper reach of the river Waldaist (Schwarze Aist) (dark green: forest, light green: grassland).

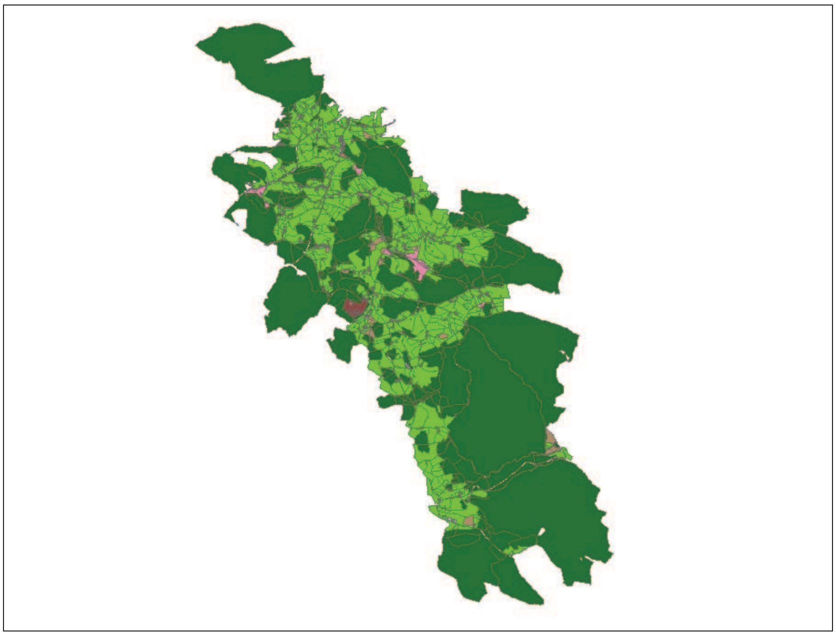


Figure 5: Land use in the catchment of the river Harbe Aist (dark green: forest, light green: grassland).

Figure 6: Land use in the catchment of the river Weisse Aist (dark green: forest, light green: grassland).

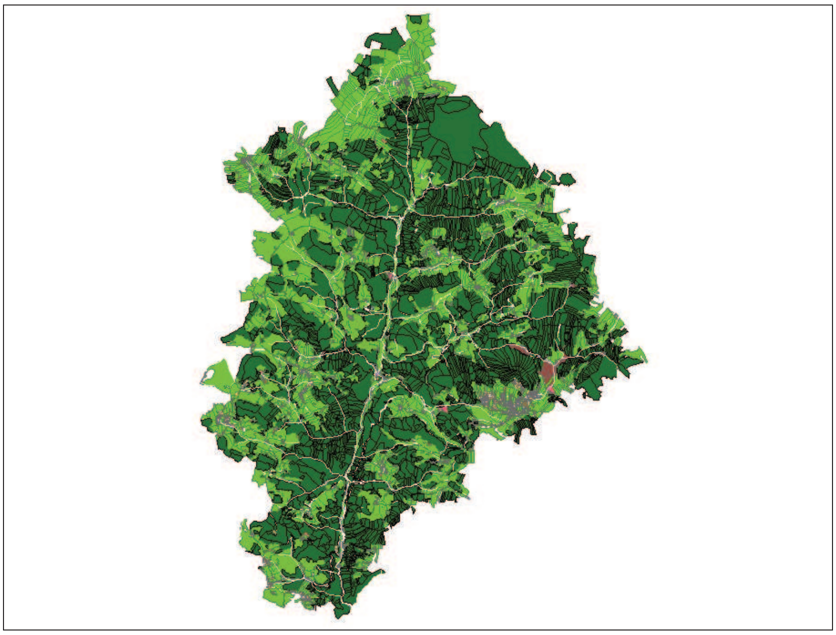


Figure 7: Land use in the catchment of the river Stampfenbach (dark green: forest, light green: grassland).

The results of the analysis of the GIS data within the four sub-catchments are given in table 3.

Table 3: Share of the most important landuse categories in the investigated catchments.

landuse	Schwarze Aist	Weisse Aist	Harbe Aist	Stampfenbach
forest	82.1	60.0	68.4	57.2
grassland	15.1	36.4	28.6	38.0
other	2.8	3.6	3	4.8

The land use data (share of forested areas) were correlated with the calculated transport rates in proportion to discharge (see figure 8). Although the mobility also strongly depends on the topology and slope of the river corridor the correlation indicates a relationship between land use and the mobility of sandy substrates in the catchment area (r^2 =0.42). Drainage measures in the catchment are the major resource for siltation processes. For a quantification of substrate input and transport rates a more detailed study in the field will be necessary.

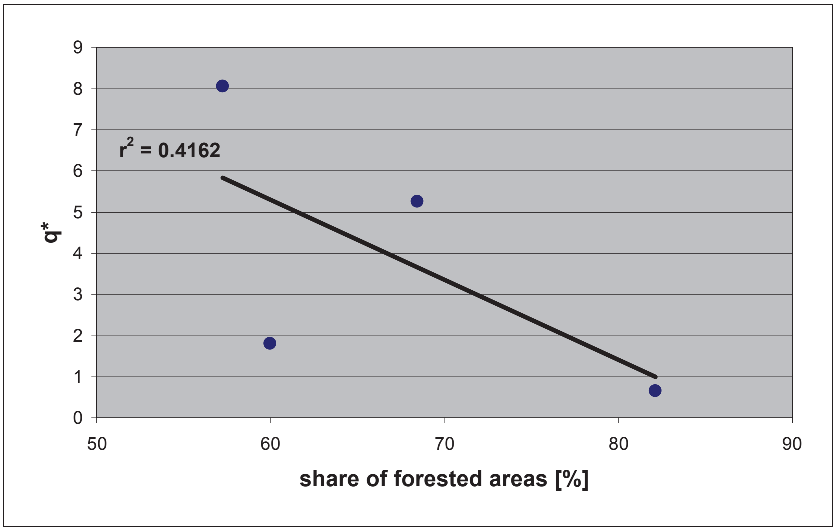


Figure 8: Relationship between the deposition of sandy substrates in relation to discharge (q*) and share of forested area in the catchment area.

Literature

Altmüller R. & R.Dettmer, 2000. Erste Erfolge beim Arten- und Biotopschutz für die Flussperlmuschel (Margaritifera margaritifera L.) in Niedersachsen. - Natur und Landschaft, 75. Jg., Heft 9/10, 384 - 388.

Amt Der Oberösterreichischen Landesregierung (Hrsg.), 1996. Waldaist, Feldaist und Aist, Untersuchungen zur Gewässergüte. Stand 1992-1995, Gewässerschutzbericht 14/1996, 119 S.

Buddensiek V. & G. Ratzbor, 1995. Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia 91: 19-24

Buddensiek V., 1991. Untersuchungen zu den Aufwuchsbedingungen der Flußperlmuschel Margaritifera margaritifera LINNAEUS (Bivalvia) in ihrer frühen postparasitären Phase. - Dissertation, Universität Hannover

Buddensiek V., 1992. The pearl mussel Margaritifera margaritifera L. in its early postparasitic life. - Arch. Hydrobiol., Supplement, im Druck

Buddensiek V., H. Engel, S. Fleischauer-Rössing, S. Olbrich & K. Wächtler, 1990. Studies on the chemistry of interstitial water taken from defined horizons in the fine sediments of bivalve habitats in several northern German lowland waters. I.: Sampling techniques. - Arch. Hydrobiol. 119: 55-64

Killingseder H.P., 1998. Abfluss- und Geschiebebilanzierung im Einzugsgebiet der Waldaist und ihren Zubringern. Unpubl. Bericht im Auftrag der OÖ - Landesregierung.

Ofenböck T., 1998. FLUP- Flussperlmuschelschutzprojekt Oberösterreich - Pilotstudie an der Waldaist. - Unpubl. Bericht 1998 im Auftrag an die Oö. Umweltanwaltschaft.

Ofenböck T., 1999. FLUP- Flussperlmuschelschutzprojekt Oberösterreich - Pilotstudie an der Waldaist. - Unpubl. Bericht 1999 im Auftrag an die Oö. Umweltanwaltschaft.

Ofenböck T., 1997. Flussperlmuschel-Schutzprojekt Oberösterreich. Pilotstudie an der Waldaist. Unpubl. Bericht i. A. der OÖ Landesregierung.

Richards C. & K. L. Bacon, 1994. Influence of fine sediment on macroinvertebrate colonization of surface and hyporheic stream substrates. - Great Basin Naturalist 54 (2), 106 - 113.

Smart G. & M. Jaeggi, 1983. Sediment transport on steep slopes, Mitteilungen der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, Zürich Nr. 64, 1983.

2.6 River Neajlov (Romania)

Carmen Postolache (UNIBUC-ECO)

2.6.1 Catchment location

Neajlov catchment is a sub-basin of Arges River catchment, an important tributary of the Danube River. Its location is in the southern part of Romania, between 43^{0}56'00"N -44^{0}49'12"N latitude and 24^{0}14'30"E-26^{0}15'36"E longitude. The relief is characteristic for Getic piedmont – a plain with low slope, covered by loess, with compacting micro-depressions and large parallel valleys oriented to NW SE.

2.6.2 Climatic/discharge/land use scenarios

Climate

The climate is temperate-continental, with transition influences from sub-Mediterranean to draughty eastern climate. Mean annual temperature is between 10^{0} (in northern part) and 11^{0} (in southern part) and multiannual precipitation is 400-600 mm. Annual mean thermal amplitude is of 25-26^{0}C, global radiation is 127 kcal/cm^{2} and relative air humidity is about 74%. The mean annual evapotranspiration is between 400 – 500 mm.

The climatic changes are expected to induce two main possible scenarios in the selected catchment:

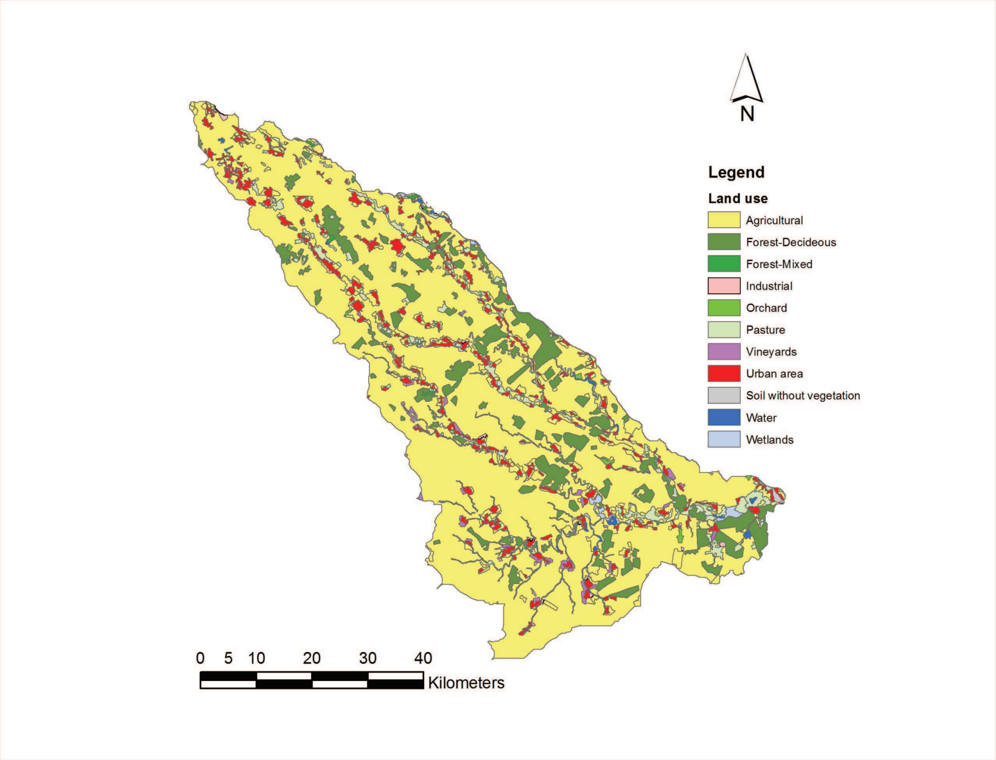
- a decrease of river discharges accompanied by a decrease of groundwater table, or
- an increase of river flows and consequently of groundwater table

Land use

The geomorphologic features, hydrological characteristics, vegetation diversity and human interventions in the last 50 years explain the actual land use in the catchment. The region is dominated by agro-systems, which represent 78.5% from total surface. Secondary forests cover 10.4% of the area and pastures 4.3%. Human-made systems cover 5.5% of the total surface area of the catchment (Fig 1).

Land use scenarios are closely connected with hydrological ones: for example, the decrease of groundwater table will induce the reduction of wetland zones and changes in land use will occur (more land will be used for agriculture). These kinds of changes occurred in the last decades in our catchment due to hydrotechical works in its south part. On the contrary, the groundwater table increase will be accompanied by an extention of wetland zones.

Figure 1. Land cover of Neajlov catchment (based on Corine database)



Scenarios:
The climatic/discharge scenarios will be obtained through mathematical modelling of hydrological processes at the catchment scale, based on data from climatic scenarios developed in consortium.

2.6.3 Collected data

Hydrological data
The number of stations where discharge measurements have been performed varied in time. We can rely on 7 stations for long-time measurements, but the number can be higher for shorter periods. Taking into account the complexity of data needed to reach the objectives of WP2 - tasks 1 and 2, we will focus on data from 3 monitoring stations located on Neajlov River.
The 3 mentioned stations are located as follows:

- Moara din Groapa - is in the the first third part of Neajlov River (km 83 from spring);
- Vadu Lat - after the confluence with Dambovnic River (km 120 from spring);
- Calugareni - after the confluence with Calnistea River (km 164).

The time series is available for at least 20 years; at this moment with have the data for the last 10 years.
The frequency of measurements varies with station: usually there are monthly measurements, but for three stations selected daily discharges are available.

Climate data
The rain data available are:

- rain;
- number of precipitation days;
- extreme daily precipitation;

- snow cover.

For the moment, these kind of data we have from one meteorological station, located in the inferior part of the catchment. We will try to obtain these informations also from another site, located in the northern part of the catchment (Pitesti).

The climatic data we have are from 1994 up to the present. Daily data for rain are available. Other data available from the meteorological station are: solar radiation, daily air Tmed, Tmin,Tmax and soil Tmed, Tmin, Tmax.

Hydromorphological data

For the description of hydromorphological characteristics at the local scale (selected points) maps 1:5000 have been used and the most important parameters has been calculated. Information from literature have been also gathered for one station (Izvoru).

Land use data have been obtained from Corine landcover map.

2.6.4 Data analysis

In order to establish relations between land-use/discharge we intend to use both regression, pattern and multivariate analysis

2.6.5 Results

To be completed.

2.6.6 Perspectives, Cause Effect Chain and Cause Effect Recovery chain

It is difficult to foresee which hypothetical Cause Effect Chain will better reflect the interactions between climate change and river hydromorphology through land use/discharge alterations. In the last decades, the dominant process was the modification and losses of habitats due to intensification of land use and we expect this will better reflect the interaction climate/discharge.

In our previous works we tried to demonstrate the importance of riparian structures in both biodiversity conservation, and in controlling the nutrient fluxes from agricultural landscapes. We consider the reconstruction of buffer zones is one of the most important management measures for improving river morphology.

2.7 The Emå Catchment (Sweden)

Leonard Sandin (SLU)

2.7.1 Study area

Geography

The Emå catchment is situated in the south-eastern part of Sweden (Fig. 1). It is the largest river in this part of the country, with a catchment area of 4472 km^2. It flows from west to east and the sources are found in the highland of Småland, just north of Storasjön, ca 10 km from the city of Nässjö. The main river then runs ca 220 km and enters the Baltic Sea in Em, at Kalmar sound. The river runs through eight municipalities on its way to the sea (starting from the sources) Nässjö, Eksjö, Sävsjö, Vetlanda, Hultsfred, Högsby, Mönsterås och Oskarshamn. Most of the river and catchment are found in the ecoregion of the "central and eastern south-swedish highland". At least six large lakes can be found in the main stem of the Emå river: Storasjön, Vallsjön, Tjurken, Grumlan, Norrasjön, and Flögen. The catchment consists of 19 subcatchments, where the main rivers are: Solgenån, Linneån, Silverån, Brusaån, Sällevadsån, Pauliströmsån, Gnyltån, Saljenån, Gårdevedaån, Marån, Morån, Nötån, Tjustaån, and Lillån.

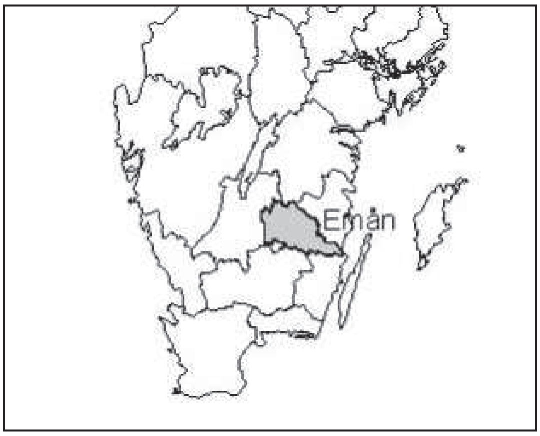


Fig.1. The Emå catchment in south-eastern Sweden.

History (all information summarized from Dedering, 2001)

People have lived in the Emå area for more than 6.000 years. The early settlements are found near the large lakes and along the Emå river itself. When man started to hold domestic cattle and grow cereals, then settlements expanded, but were still concentrated to the Emå valley. Later on (2-3.000 years ago) the settlements changed and were more concentrated to higher areas in the landscape instead of directly at the rivers or lakes. The cattle were grazing in the large wetlands formed along the river, where the flooding of the river was important, since this made nutrients from the river water available for grasses, then used for grazing. Later on, as the climate became cooler, it was no longer possible to have the cattle outdoors all year round. The cattle had to be stabled during winter, which meant that fodder had to be harvested and stored for the cold season. The fodder was mainly taken from meadows, which became the common way to get food for the cattle for the farmers almost into our days. Before industrialization in the 19th century and the urbanization in the 20th century, people lived off what the land and forest gave. The people lived in villages or at small farms; the villages consisted of a large number of houses within a very small area. Every house on the farm had its own purpose, e.g. for living, hay, cattle, sheep, and baking. Near the farmhouse of the village were the meadows and the fields, where the fields were small and scattered within the much larger meadows. The meadows and fields were fenced, so that the cattle and wild animals couldn't get to them. When the villages grew, the land was divided into smaller and smaller parts, where each farmer owned many very small pieces of land. In the 19th century, the ownership of the land was shifted, so that each farmer had all his land next to each other; this was a very large reorganization of the agricultural land. In the same period large land areas were transformed to agricultural land (fields), both meadows, bogs, and marshes were used, and lakes were lowered to get new land. The population also grew markedly in this period (by 135% from 1750 to 1880).

It is not certain how important the Emå river has been for transportation in pre-historic times. It seems as if it was a more important means of transportation in winter (when the lakes were frozen) than in summer. People and goods have, however, always been transported on the river, at least in certain deeper, more straight parts of the river. The river has been straightened and large objects have been removed for timber transport, watermills, sawmills, and power stations etc. The smaller rivers and streams in the Emå catchment have been less suited for timber transports, because of its low slope and many meanders. The lower parts of the river (in the county of Kalmar), were declared general timber route in 1897, and was first used in 1912. Normally ca 25.000 cubic meters of timber was moved down the river each year, and this business did not end until 1963. Timber has also been moved down the smaller streams, at least in Sällevadsån, Lillån, and Silverån. In early days, every village in the forest areas had a water mill. These were of two kinds, the Skvaltkvarn with a horizontal wheel, which was well suited for smaller rivers and streams, these disappeared in the 19th century and were replaced by larger hjulkvarnar ("wheel mills"), where the wheel were placed vertically. There were literary thousands of watermills in the Emå catchment in older days, e.g. in one parish in 1772, there were 194 skvaltkvarnar and 27 sawmills. These all disappeared in the 20th century and in an inventory for the first economical map of the Emå area in 1940s and 50s, 84 watermills and indications of ca another 100 were found. One of the first water power stations in the Emå was built at Finsjö in 1903. There are at least 23 power stations in the Emå catchment today and more than 100 dams. In the biotope inventory of the streams and rivers in the Emå catchment in the mid 1990s (Halldén et al., 1999), 292 fish migration barriers were also found.

Water quality

The water quality in the Emå catchment is dependent both of diffuse input from e.g. agriculture and waste water, but also from point sources, such as paper mills and metal industries within the catchment. The recipient control of the water quality in the Emå catchment has been going on since 1992 (http://www.emans-vattenforbund.com). The transport of nitrogen and phosphorous has increased by between 16% and 100% in different parts of the catchment during this period. The phosphorous and nitrogen levels in the lakes are generally "high" in the downstream parts of the catchment according to the Swedish Environmental Quality Criteria (Swedish Environmental Protection Agency, 2000), and in the upper parts "moderately high" or "low". The pH are "almost neutral" or "midly acid" in the whole catchment. The extent of water color is "extremely intense" or "very intense" in large parts of the catchment (especially in the south-west). The oxygen level is "abundant" or "moderate" in almost all of the catchment, whereas the extent of turbidity of the water is "moderate" or "significant" in most cases. The concentration of metals in the water are in most cases "very low" or "low", but in some areas of the catchment increasing significantly from 1999 to 2003 (Emåförbundet 2003), especially for aluminum, cadmium, and lead, but there are also decreases in metal concentrations in certain streams/rivers.

Geomorphology

The river slope in the main stem of the Emå river is 268 meters along the 220 km of the river. The highest points are found at 330 m.a.s.l. in the west, and 0 m.a.s.l. where it falls into the Baltic in the east (Fig. 2). Most of the geology in the catchment is made up of granites, but there are also areas with more easily weathered rock types such as diorite and gabbro. The earth is mainly made up of moraines, poor in nutrients and with large blocks, boulders and stones. The western parts have, however, generally a more nutrient rich content and also a more calcareous content. In the eastern parts of the catchment, in the county of Kalmar, the earth cover is very thin or non-existent, so the rock is in many places visible. The Emå valley on the other hand is rich in clayey or sandy morains which are good for agriculture. The highest coastline of the last glaciation lies in the Emå area at 110 m.a.s.l., this means that only a smaller part in the east of the catchment can be found below the highest coastline, whereas the area in the western and central part of the catchment were above the highest coastline. This has great implications for the earth material, where the higher areas below the highest coastline have lost all fine sediments, which has been transported to the lower areas by the water. This is not the case for the areas above the highest coastline.

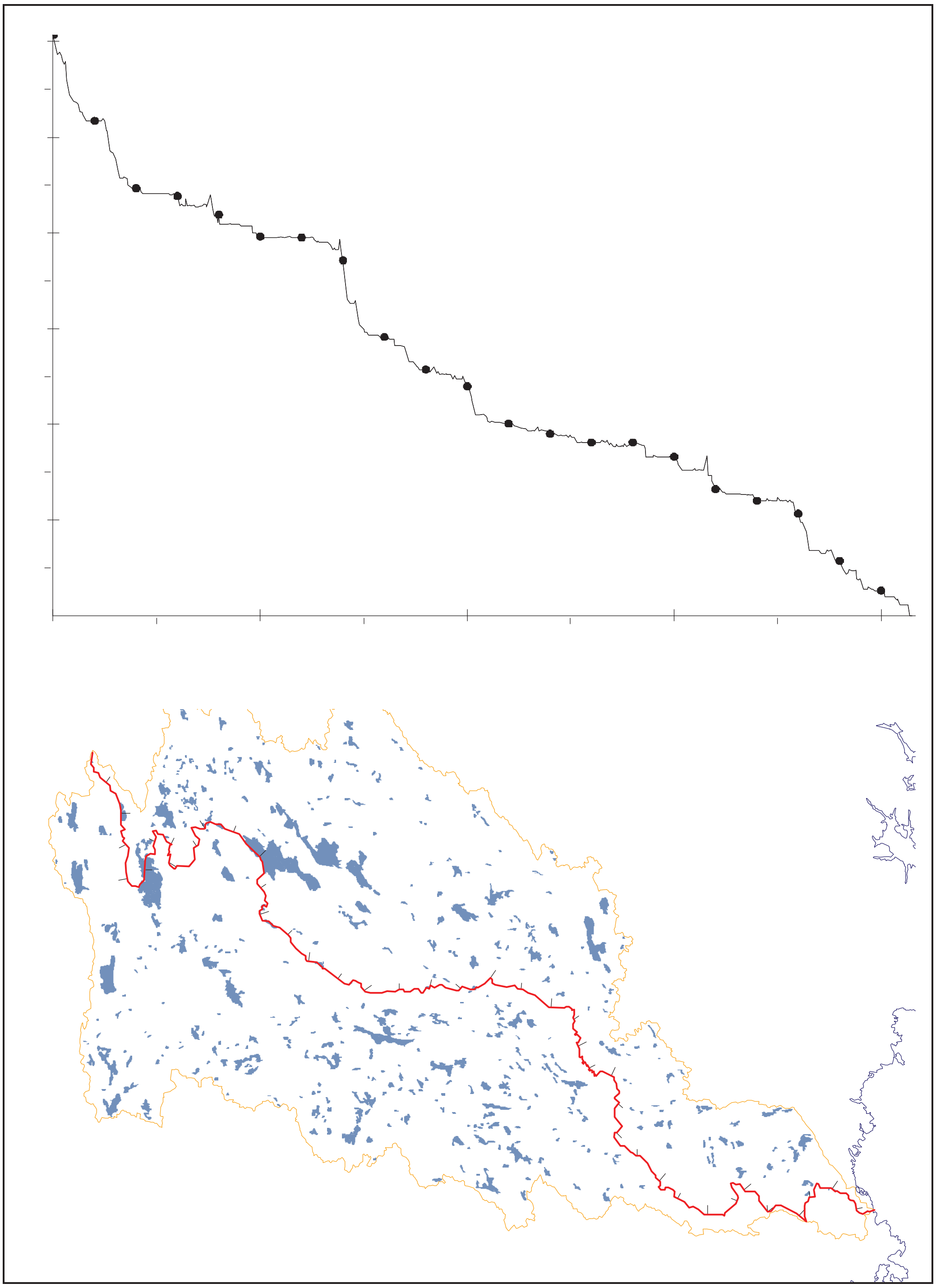


Fig. 2. Slope of the main stem of the Emå river.

2.7.2 Collected data

Climate and hydrology

The mean January temperature is between -4 and -2 °C and the mean July temperature is between 14 and 18 °C (National Atlas of Sweden, 1995). The mean yearly precipitation is between 500 near the coast and 700 mm in the western higlands. The growing season is 180 to 210 days. The mean discharge just upstream of the river mouth is 30 m^3/s (mean value from 1926-1975), the lowest discharge being 2 and the highest 270 m^3/s. The large difference is due to the fact there are no larger lakes or other water magazines in the lower part of the river. The monthly discharge between 1996 and 2003 varied between 5.5 in September of 2002 and 96.7 m^3/s in July 2003 (Fig. 3).

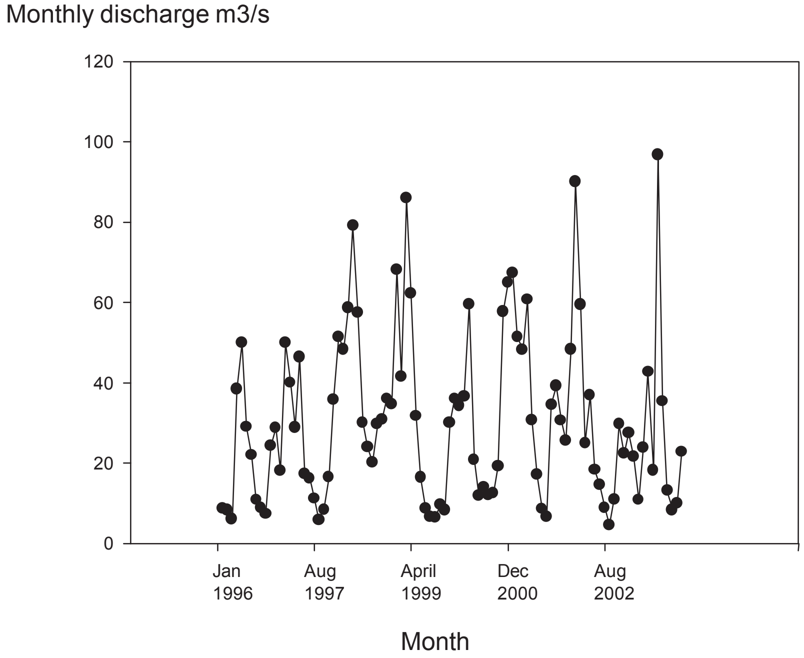


Fig. 3. Monthly discharge at Em, near the mouth of the Emå river. Discharge calculated using the Swedish Meteorological and Hydrological HBV/Pulse model.

Land-use

Forest is by far the most common land use type within the Emå catchment (74%) (see Fig. 4). The Emå valley has, however, been used for agriculture for a very long time (see history). The forests in the catchment are dominated by pine and spruce, but there are also important areas with deciduous forests. The lake area of the catchment only comprises 6% of the total area, where the total lake area is ca 300 km^2.

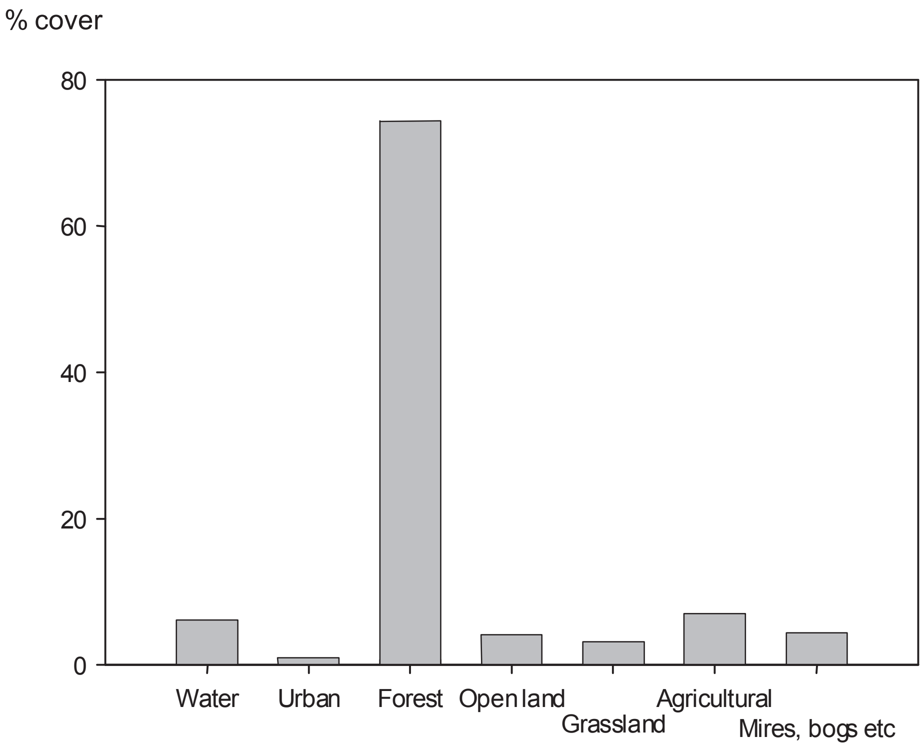


Fig. 4. Land-cover in the Emå catchment.

Climate scenarios

According to the climate scenarios for the south-eastern Sweden, where Emån is situated, there will be less frequent floods, and less total discharge in the rivers (Andréasson et al., 2004). More of the water will come into the system during winter and less during summer.

Stream morphology

The larger streams/rivers within the Emå catchment were mapped using the biotope inventory method (Swedish Environmental Protection Agency, 2003). A total of 1624 river stretches were inventoried for e.g. bottom substratum type, vegetation in the stream, water velocity, near stream vegetation, and transverse structures. A total of 762.313 meters of stream length were mapped in this way, within the 19 subcatchments. The mapped lengths within each subcatchment differed from 100.478 meters (13.2% of the total length) in the subcatchment consisting of the lower parts of the main stem of the Emå catchment, to 11.561 meters (1.5%) in the Torsjöå subcatchment. The stream velocity of each stretch were divided into four categories, from slow flowing (<0.2 m/s) to (>0.7 m/s) the % of stream length within each stream section were scored into one of four categories from 0 = no cover to 3 = =>50% cover. Almost all (except five stretches and < 0.5% of the stream length did not have one stream category scored as a “3” i.e. with a total cover =>50% of the area. The slow flowing sections were clearly the most abundant, where 56.6% of the river lengths had a slow flowing velocity (<0.2 m/s), consisting of 40.1% of the river stretches. The fast flowing water were clearly the rarest with 1% of the length and 2.3% of the river stretches, whereas the slower of the two middle categories were more common (29.8% of the length and 30.0% of the river stretches) than the more fast flowing one (12.6% of the length and 26.7% of the stretches). The form of the river were divided into three categories “straight” “sinuous” and “meandering”, where the sinuous type was clearly the most common, 69.5% of the length and 64.5% of the river stretches, the straight stretches consisted of 23.9% of the length and 33.3% of the stretches, whereas the meandering parts of the river comprised 6.7% of the length and only 2.3% of the number of stretches mapped.

2.7.3 Data analysis

Using the biotope data from the Local County Board of Jönköping, the relationship among different local hydrological and morphological features of the streams and rivers can be evaluated. Those has partly been done by simple box and whisker plots. The relationship between these in-stream variables were analysed using Principal Components Analysis (PCA) and the relation to the near-stream zone (riparian vegetation) were analyzed using Redundancy Analysis (RDA), in the program CANOCO for windows, version 4.5.

2.7.4 Results

The slow flowing sections were clearly the most abundant, where 56.6% of the river lengths had a slow flowing velocity (<0.2 m/s), consisting of 40.1% of the river stretches. The fast flowing water were clearly the rarest with 1% of the length and 2.3% of the river stretches, whereas the slower of the two middle categories were more common (29.8% of the length and 30.0% of the river stretches) than the more fast flowing one (12.6% of the length and 26.7% of the stretches) (Fig. 5).

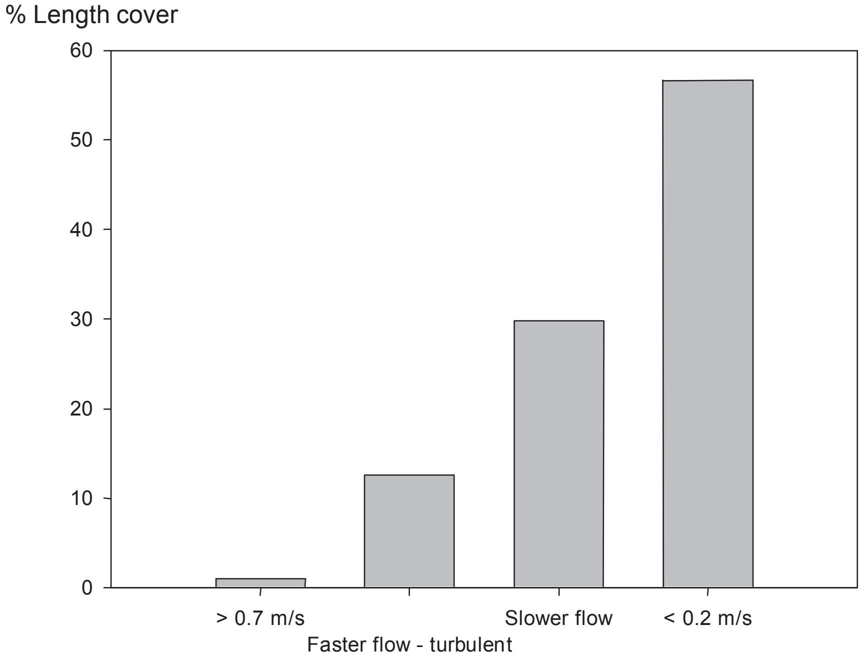


Fig. 5. Percent length cover of different stream velocity types.

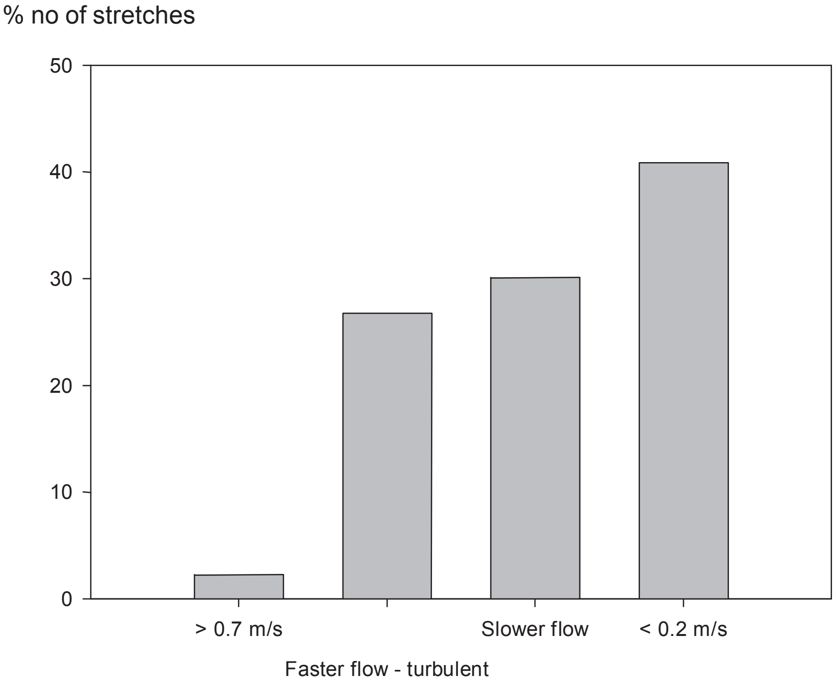


Fig. 6. Percent number of stretches with different stream velocity types.

The form of the river were divided into three categories “straight” “sinuous” and “meandering”, where the sinuous type was clearly the most common, 69.5% of the length and 64.5% of the river stretches, the straight stretches consisted of 23.9% of the length and 33.3% of the stretches, whereas the meandering parts of the river comprised 6.7% of the length and only 2.3% of the number of stretches mapped.

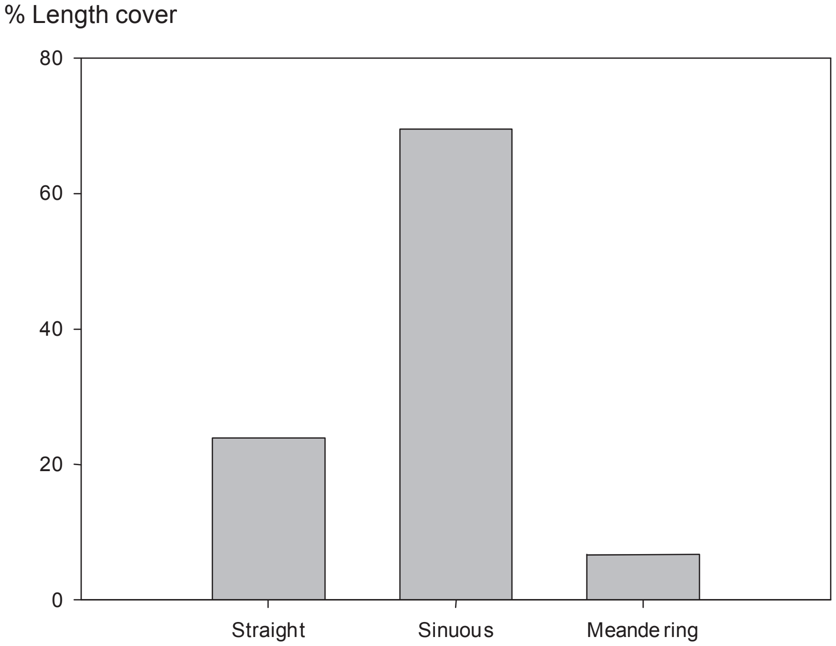


Fig.7. Percent length cover of different stream forms.

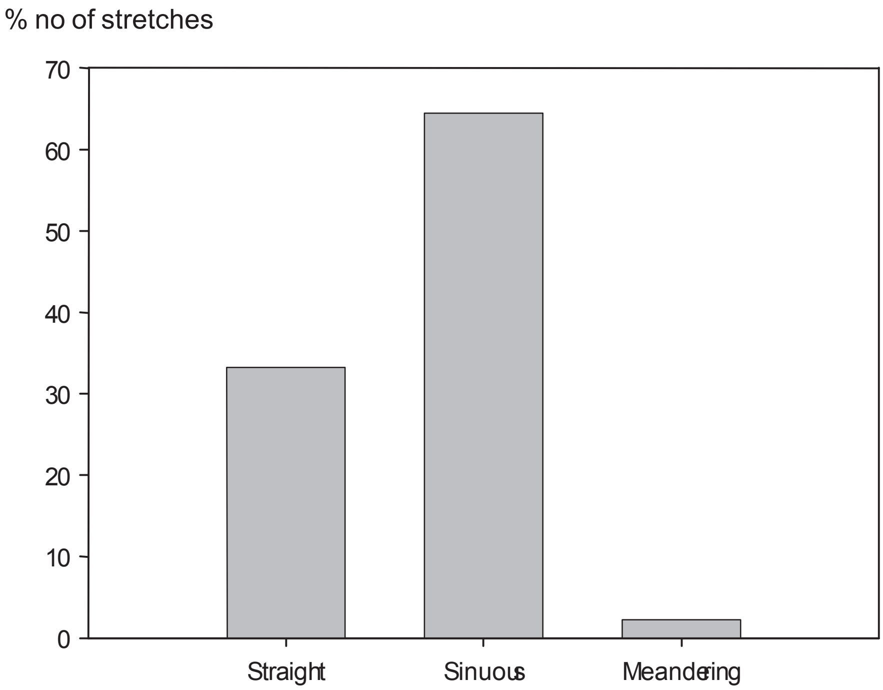


Fig. 8. Percent number of stretches with different stream forms.

The relationship among different substratum types and in-stream vegetation showed a clear pattern, where along the first axis of the PCA there was a gradient from detritus, sand, clay with emergent and floating vegetation to the left (negative scores) to cobbles, blocks, and rocks with mosses, *Fontinals spp.* and filamentous algae to the right (positive scores) of the ordination diagram (Fig. 9). The second axis was more difficult to interpret. There seems to be division with sites having sand, pebble, and cobble substratum with rooted vegetation of different types (towards the bottom of the ordination) versus sites with either clay or blocks or rocks as the main substratum type with moss vegetation and detritus.

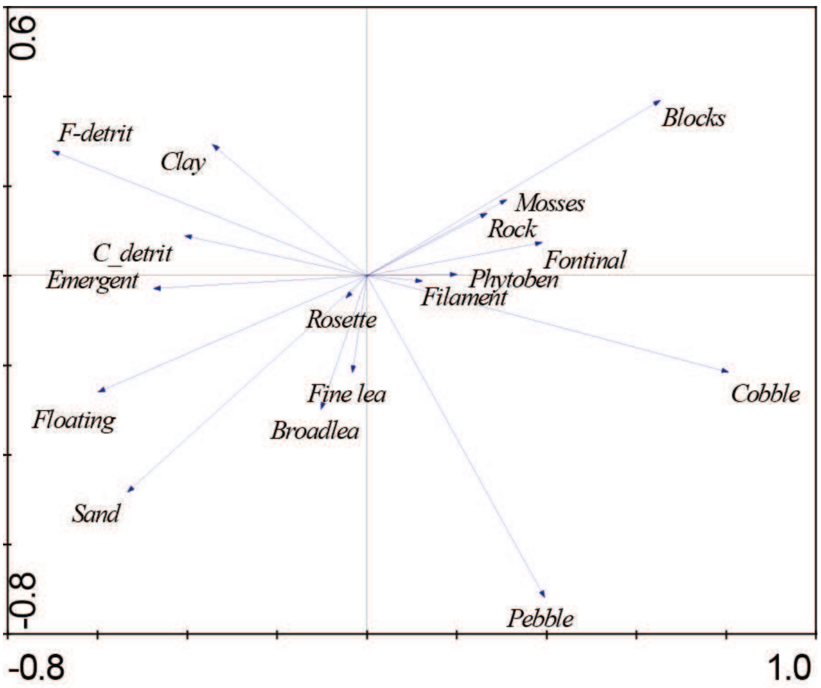


Fig. 9. In-stream variables from the Emå biotope inventory. Relationships assessed using principal Components Analysis.

The relationship among in-stream variables such as substratum composition, stream velocity and the amount of dead wood in the stream (Figure 10) were also related to near stream parameters such as shading, vegetation along the left and right bank in an area of 30 m along each bank and also in the surroundings, defined as the vegetation type in a 200 meter wide zone on each side of the stream.

Fig. 10. In-stream variables in Redundancy Analysis.

Out of the 69 explanatory variables, eleven were chosen in a RDA forward selection procedure, where variables explaining > 1.5% of the total explained variation (TEV) and being statistically significant ($p < 0.001$) were included (Figure 11). All explanatory variables explained 17.2% of the total variation in the dataset, whereas the eleven chosen variables explained 13.0% of the total variation and 76.5% of the TEV. Clearly the most important of these variables were shading along the banks of the river or stream, explaining 39.0% of the TEV, followed by the mean depth explaining 11.0% and whether of not the stream were meandering, explaining 4.7% of the TEV (Table 1).

Table 1. Explanatory variables chosen using forward selection in Redundancy Analysis using near-stream and surrounding land use etc variables as explanatory and in-stream characteristics such as substratum, vegetation composition and stream velocity.

Variable	% Explained of TEV
Shading	39,0%
Mean depth	11,6%
Meandering	4,7%
Minimum width	4,1%
Dams	3,5%
Right bank open land	3,5%
Wetland	2,3%
Max depth	1,7%
Straight channel	1,7%
Agricultural land	1,7%
Open land	1,7%

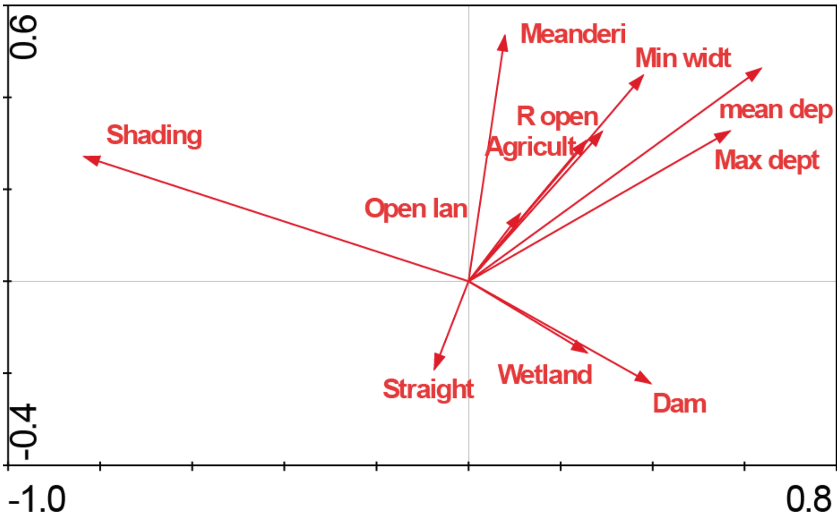


Fig. 11. Significant explanatory variables explaining > 1.5% of the total explained variability in a Redundancy Analysis.

2.7.5 References

Andreasson J., S. Bergstrom, B. Carlsson, L.P. Graham & G. Lindstrom, 2004. Hydrological change – climatic change impact simulations for Sweden. Ambio 33 (3-4): 228-234.

Dedering C., 2001. Kulturhistoria ur dimma. Emåns avrinningsområde (in Swedish). Länsstyrelsen i Kalmar Län, 31 pp.

Emåförbundet, 2003. Beskrivning av tillståndet i Emåns avrinningsområde 2003 samt en beskrivning av trender under perioden 1992-2003 (in Swedish).

Halldén A., A. Bäckstrand, B. Lind & T. Haag, 1998. Biotopkartering Emån. En kartering av biotoper i och i anslutning till vattendrag inom Emåns avrinningsområde (in Swedish). Meddelande 99:20 from Länsstyrelsen i Jönköpings Län.

National atlas of Sweden, 1995. Climate, lakes and rivers. Almqvist & Wiksell International.

Swedish Environmental Protection Agency, 2000. Environmental Quality Criteria – Lakes and Watercourses. (Report no. 5050).

Swedish Environmental Protection Agency, 2003. Handbok för miljöövervakning, undersökningstyp: biotopkartering vattendrag (in Swedish). Version 1.

2.8 Becva catchment (Czech Republic)

Karel Brabec, Ondrej Hajek, Karla Petrivalska, Libuse Opatrilova, Hana Kvardova, Vit Syrovatka (Masaryk University)

2.8.1 Climatic/discharge/land use scenarios

For the construction of the climate scenarios for the Czech Republic were used 2 models (GCM) corresponding with the climate of Central Europe (SRES B1, SRES A2). Only lowest and highest extreme estimates were evaluated for each model. Time horizon of scenarios is 2050. The impacts of climate change on the hydrological regime were studied for selected catchments and some general conclusions could be expected in our model catchment of the Becva River. The application of the BILAN and CLIRUN models was based on assumption that climate change would not directly affect land use. The SAC-SMA model reflecting potential changes of the vegetation cover was applied as well.

The simulations demonstrated that the runoff changes are closely related to the change of the annual precipitation pattern. The annual distribution of the air temperature should be taken into account. The impact of climate change would be more severe in low flow periods and in catchments with low capacity for natural groundwater accumulation. The flysh geology which dominates in the model catchment is associated with rapid runoff of rainfall. This would emphasize effect of extreme floods (in cold period), summer-autumn droughts and more frequent flow extremes, phenomena being predicted as a consequences of climate changes. Precipitation decrease in summer (esp. August, September) and increase in winter or in October are expected by all models.

Possible land use scenarios in the model catchment are: changes in riparian zone – extension/restoration of buffer zone of river, predominantly replacing cropland areas.

Problems for the catchment

It was started activities combining restoration and flood protection. Recently, it will be important to support the decission process with results of ecological studies. There is lack of information on aquatic biota. As a serious problem could be considered the realization of the age-old idea of Oder-Elbe-Danube navigation canal, because studied segment of the Becva River is a part of planned course.

2.8.2 Collected data

Climatic/discharge data

In Becva catchment 4 stations are used for the discharge measurement (see Fig. 1). Their positions are: one closing site of the catchment, 2 on the main tributaries, one headwater site (see the Fig. 1)

Time series since 1978 will be available for analyses (except one station where data are measured since 1985). Water level is recorded continuously and day average of discharge will be available for us.

Rain data available are precipitation records (day amount) from 3 stations, referred to 30 years with day amount frequency. Other climatic data available are air temperature (day average calculated from 3 values) from 4 stations. Discharge and climate data would be available until April 2005.

Hydromorphological data

The results of specific hydromorphological analyses are available. For the studied sites Osek and Cernotin are available (Sindlar, 2000):

average floodplain width defined by inundation Q50
length of channel
length of valley floor
bottom level at upstream end point
bottom level at downstream end point
average channel width

average channel depth
average slope of valley floor
The width of riparian vegetation was recorded from aerial photos in interval of 100 m for studied stretches and in interval 1 km within 42 km long section of the Becva River. Additional hydromorphological surveys are planned for year 2005 linked to biota surveys.

Land use data
Land use data are: CORINE LAND COVER. CORINE LAND COVER vector shapefile, orthophotos, stream network and subcatchments shapefiles, digitalized map of surface water regions (1:500000). Information was provided by the Ministry of Environment, the Water Research Institute TGM and the Land Survey Office.

2.8.3 Data analysis

The interactions between hydromorphology/hydrology and land use within studied catchment are fixed by regulation which purpose is protection of anthropogenic activities in the floodplain. The initial analyses were focused on analyses of existing data based on aerial photos, GIS layers, comparison with historical information. Complex evaluation will be done after collection additional data from field surveys at pilot stretches. The first step of analyses resulted in large scale description of catchment, subcatchments and buffer areas in terms of land-use and hydrological classifications. Futher analyses will be based on the smaller scale (stretch, transects, habitats) characteristics gathered in the linkage to biological data (2005, 2006).

2.8.4 Results

Hydromorphology-landuse relationships
The interactions between hydromorphology and landuse within the pilot catchment of the Becva River have a historical development. Agricultural and settlement activities were kept off the river until the end of 19th century. During this period the Becva River was regulated systematically which resulted in controlling medium floods with annual periodicity.

Research question
What are the key parameters describing linkage between hydrology, landuse and hydromorphology in the pilot catchment of the Becva River?

General information on study catchment

Regulation of Becva River (1880-1933)
Geological, climate and hydrological characteristics of the Becva River catchment caused periodical flooding of areas around the water course. The flood protection of settlements and cropland by constructing the embankment changed the original character of the meandering and anastomosing channel. The channel cross-section was modified to a trapezoidal shape with a bottom width of 35 m, slope of banks 1:3 and banktop height of 3 m.

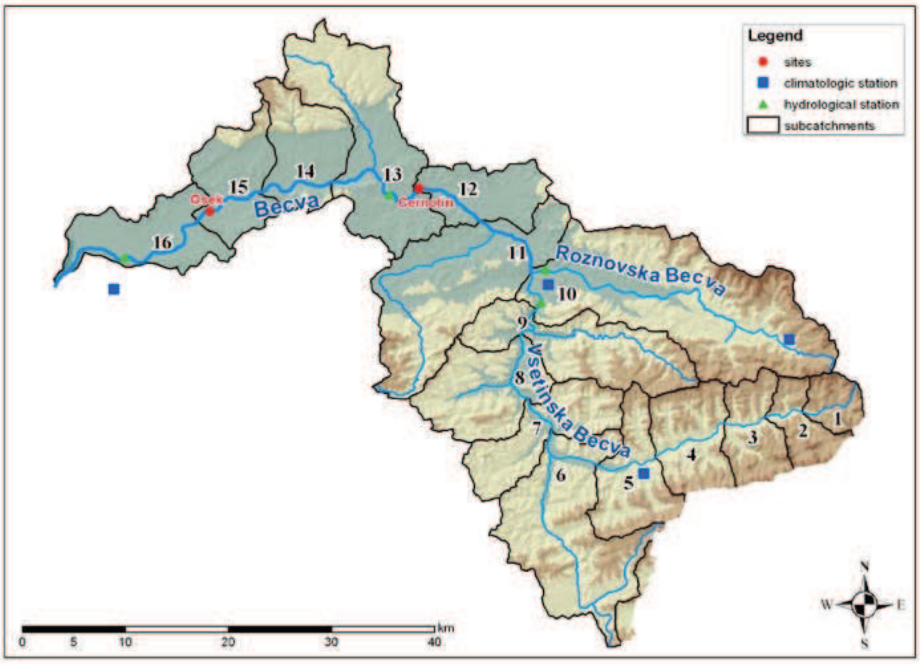


Fig. 1. The catchment of Becva River was devided into 16 subcatchment for some analyses. Locations of the pilot study sites near Osek and Cernotin are marked together with measuring station of Czech Hydrometeorological Institute from which discharge, precipitation and temperature data will be available.

The straightening and resectioning of the channel and the reinforcement of banks reduced natural river-bed evolution, prevented lateral movement of the active channel within the floodplain, reduced the diversity of aquatic and floodplain habitats and isolated the channel from the riparian zone – modification of water regime in floodplain. The channel dimensioned to drain floods of medium magnitude (up to 412 $m^3.s^{-1}$) allowed the expansion of cropland to the floodplain, usually near the banktop. Biodiversity of the riverine landscape was reduced by the loss of the mosaic of species-rich floodplain medows and wetland habitats. Although residual floodplain forests maintained, mainly biotops of softwood forest were affected by changes in the water regime of the floodplain (drop of groundwater level).

Catastrophic floods (Q_{100} and higher) altered the fluvial topography of the riverine landscape (1880, 1910, 1941, 1997). The dominant processes in low-slope gravel rivers are the lateral errosion broadening the channel and the redistribution of sediments (Sindlar, 2000). The maximum peak discharge during the floods in July 1997 was 838 $m^3.s^{-1}$ (Q_{100} = 685 $m^3.s^{-1}$). In addition to the human tragedy there was also large material damage, which also affected the structures built for regulation of the river in the beginning of the 20th century. Based on the agreement between Water Basin Authority and Agency for Nature Conservation and Landscape Protection of the Czech Republic it was decided to maintain five relatively short river stretches in the "destroyed" state (see Fig. 1). It was found that some natural hydromorphological features were restored to the state documented from the period before regulation (historical maps and records). The new active floodplain of the restored sections has a flooding periodicity similar to conditions before regulation (from Q_{30d} to Q_1). Due to scouring associated with regulation the terraces were formed in the new channel. This channel is wider than regulated the one, but the time needed to reach the dynamic equilibrium is questionable considering the effect of slope and also the fact that active floodplain width is not enough for the lateral stabilization of errosion.

Data evaluation

A 600 m wide buffer centered to the axis original channel was delineated along a 61 km long river segment, and it was devided on the 1 km-long buffer sections. The proportion of Corine land cover categories was determined within individual buffer sections. The categories were merged into categories used in AQEM project. The cropland dominated within this buffer area (59.8 %), followed by 15 % of urban area and 20 % of forests. Compared with values based on analyses of the entire subcatchments defined by starting and end points of the studied river segment) river corridor has higher proportion of cropland (see Table below).

Landuse category (AQEM)	Entire Becva catchment	Vsetinska + Roznovska Becva
urban sites	5,58	4,36
urban sites (industrial)	0,46	0,28
others	0,14	0,00
crop land	43,46	31,87
pasture	2,87	3,65
deciduous native forest	3,94	2,91
coniferuous native forest	24,17	33,59
mixed native forest	17,58	21,41
alpine heath	0,14	0,02
grass- and bushland	1,58	1,86
standing waters	0,08	0,04

Additionaly the landuse in longitudinal river profile was evaluated. Forests covers from 90 % area in the source part of the Vsetinska Becva River to 47 % at confluence with the Morava River (Fig. 2).

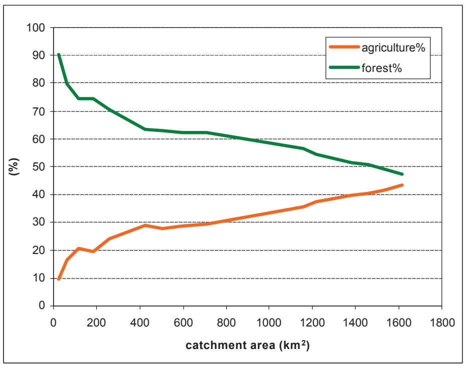


Fig. 2. Longitudinal trend of agricultural and forest landuse along the Becva River related to catchment area (cumulative values upstream the subcatchments delineated at figure 1).

2.8.5 Perspectives, Cause Effect Chain and Cause Effect Recovery chain

Perspectives for the selected study catchment.

The protection based on status of National Nature Reserve is planned for the site Osek. Some other sites of comparable value could be degraded by contruction of polders or reservoirs being discussed as potential solution of flood protection. Hydromorphological studies confirmed that these naturaly restored sites represent hydromorphological conditions rare in the Czech Republic where the majority of river courses of that type are completely regulated (reinforced, resectioned, straightened, impounded).

Cause Effect Chain expected

The withdrawn of human disturbance from the floodplain following catastrophic floods was realized in the Becva River catchment at 5 segments. There were allowed channel forming processes leading to more natural conditions being documented 150 years ago on the historical maps (see Appendix B).

management measures

The flood discharge changed channel morphology to the conditions similar in some characteristics to reference status. The feature contributing to improved hydromorphology are wider and not uniform channel, restoration of riparian vegetation where natural succesion is not efficient. The even wider corridor would be needed to reserve for errosional-depositional processes forming channel in near natural way. The artificially scoured channel bottom is also serious problem for the restoration of floodplain.

Despite the bank reinforcement the summer floods in 1997 were channel-forming event which also altered land use in the the floodplain. Comparing aerial photos before and after floods is obvious increasing spatial heterogeneity of alluvial habitats, higher variability of channel width (see Appendix A). The succesion of vegetation on the newly formed grevel bars is documented by botanical studies (Lacina, 2003).

2.8.6 References

Hladny J. et al., 1997. Impacts of a Potential Climate Change on Hydrology and Water Resources in the Czech Republic. Praha 1997. 135 p.

Kalvova J. et al., 1996. Climate Change Scenarios for the Czech Republic. Praha 1996. 101 p.

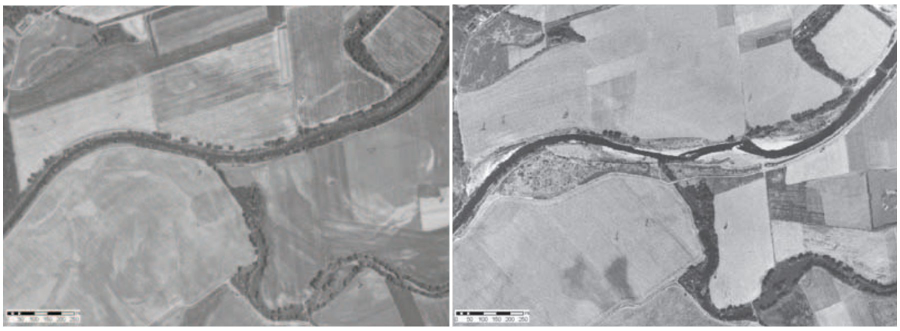
Lacina J., 2003: Succesion in the flood beds of Moravian rivers on example of Becva and Desna Rivers. In: Mekotova J. & Sterba O., Proceedings of conference “River landscape”, UP Olomouc, p. 130-139.

Sindlar M., 2000. The evaluation of alternative concepts of the Becva River restoration: hydromorphological potential of river inhabited by *Gobio kessleri*. Study report (in Czech).

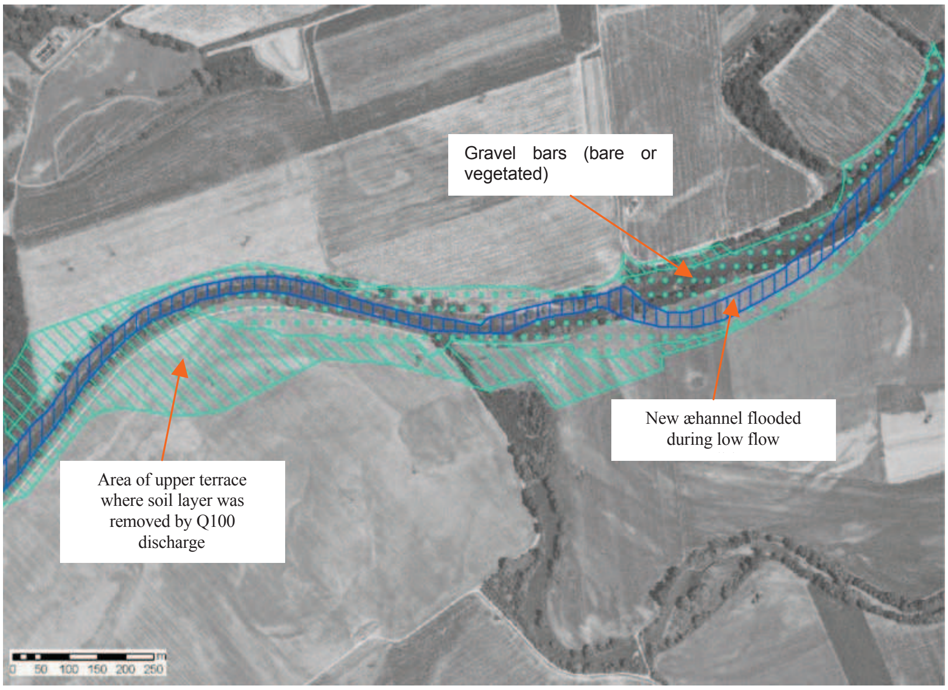
2.8 *Becva catchment*

Appendix A

Changes in landuse induced by floods (Osek site).



BEFORE AFTER



2.8 *Becva catchment*

Appendix B

Becva river near Osek on the historical map (2^{nd} military mapping, 1819-1858, source the Ministry of Environment). Meandering, anastomosing, mid channel bars or islands are documented. The wider buffer strip without arable land partly moderated the conflict between anthropogenic activities in the floodplain and highly variable flow regime of the Becva River.

3 SUMMARY OF SCENARIOS EXPECTED, DATA COLLECTED, DATA ANALYSIS METHODS, RESULTS AND CAUSE-EFFECTS CHAINS EXPECTED

3.1 Lambourn catchment

Local scenarios expected

Climatic: warmer and marginally drier in summer by 2080, with more rainfall, and more frequent intense rainfall events in winter. Winters become less cold and spring arrives earlier in the year.

Discharge: summer flows reduced and more frequent droughts. Winter flows may increase with flood events becoming more frequent.

Land use: new crops will be introduced, along with new pests. Domestic, agricultural and industrial water use will become an even more pressing issue. Increased flooding frequency would result in a withdrawal of arable practices and urban areas from the floodplain and a reversion to extensively managed meadows. Alternatively, would be that flood defence works would be placed along the river corridor to maintain current agricultural practices and protect urban areas. Over the past 50 years the proportion of the catchment in tillage has risen dramatically, replacing improved pasture and semi-natural meadows as the most common land use. We will attempt to predict the consequences of a continuation in this trend and as an alternative the reversal of this trend.

Source of information: UK Climate Impacts Programme and existing literature.

Local problems

At the moment the catchment is relatively un-impacted. The main pressures on the river are from diffuse agricultural pollution and domestic waste. There is some abstraction of water for aquaculture towards the lower end of the catchment. The river is managed carefully to maintain a sustainable trout population as a commercial angling resource.

Collected data

Discharge data*:* collected in four discharge gauges, with daily frequency, time period of record from 1962-present.

Rainfall data*:* collected in seven sites, with daily and hourly frequency, with different time periods.

Other climatic data: maximum and minimum air temperatures, soil temperature parameters, wind direction and speed and sunshine amount.

Hydromorphological data*:* recorded at 25 sites with River Habitat Survey methodology.

Land-cover data*:* satellite-derived land-cover data acquired for the catchment from the 1990 Land Cover Map and the 2000 Land Cover Map. This data was converted to the EUNIS Level 1 Habitat classification.

Data analysis

Relate variation in Level 1 and 2 HQA scores across 25 RHS sites along the R. Lambourn to land cover at three different spatial extents; catchment, riparian corridor (200m wide zone upstream of site to source) and local area (250m radius around site) using multivariate ordination (RDA). Then related variation in Total HQA score to arc-sine transformed % land cover (EUNIS Level 1) at three different spatial extents using multiple regression.

Results

RDA found that 47.1% of the variation in Level 1 HQA scores could be accounted for by the statistically significant explanatory model defined by the % cover of Broad-leaved woodland, Arable (cereal) and Improved grassland within a 250m radius of the RHS site. This was an improvement on the Level 2 HQA variables relationship with local land cover suggesting the amalgamation of information to this level clarifies the relationship. Broad-leaved woodland are associated with an increase in in-stream vegetation and a decrease in the prevalence of Bank features. Bankside vegetation and tress and riverbed substrate diversity seemed to be negatively affected by a greater occurrence of Arable (cereal) and Improved grassland in the local area around a site. However the converse is true for river channel feature and to a lesser extent flow diversity. From these preliminary analyses it could be tentatively implied that any change to climate that caused a decrease in the extent of arable (cereal) and improved grassland in the floodplain could lead to a shift in river hydromorphology from sites characterised by a diverse range of flow types, emergent herbs and submerged, fine-leaved plants to sites featuring more emergent reeds, floating and free-living amphibious plants and greater bank face vegetation structure.

Perspectives, Cause Effect Chain and Cause Effect Recovery chain

More frequent and more severe summer droughts and more frequent and intense winter floods will cause an increase in substrate erosion and transport in winter but conversely an increase in fine sediment deposition in summer. From recent studies in the Lambourn it may be that the summer droughts and associated physical changes to the river hydromorphology would have a more detrimental impact on the biota than winter floods (Wright *et al*. 2004). The projected climate change will lead to changes in catchment land-use, in particular on the floodplain: a withdrawal of intensive arable agriculture from the more frequently flooded riparian corridor and a reversion to wet meadows and grazing pastures and perhaps even an increase in wet woodlands.

3.2 Orco and chiusella catchments

Local scenarios expected

Climatic: a general warming is expected, with summer warming peaks reaching locally 10°C. Reduced snow cover. A decrease of precipitations in summer, an increase in extreme precipitation events in autumn-winter.

Discharge: increase of winter discharge, change in the timing of flows with a shift from a winter minimum to a late summer minimum and a more dynamic discharge regime.

Land use: reduction of agricultural areas, forested areas and urban growth.

Source of information: existing literature and local autorities.

Local problems

High discharges and floods in autumnn which could become more frequent and intense. Change in timing of flows, with a shift from a winter minimum to a late summer minimum and an increase in severity of droughts in summer. Greater impact of the expected demographic grown on the upstream sections of the catchments.

Collected data

Discharge data*:* collected in 3 discharge gauges, with daily frequency referred to 2002-2003.

Rainfall data*:* collected in nine sites, with monthly frequency, with different time periods.

Other climatic data: maximum and minimum air temperatures, soil temperature parameters, wind direction and speed and sunshine amount.

Hydromorphological data*:* recorded at 23 sites with River Habitat Survet South European (RHS SE) methodology.

Land-cover data*:* catchment Corine land-cover data (2000), land cover data referred to a 300 metres wide area along each river bank from interpretated aereal photos (source:ARPA Piedmont, available only for Orco river) and RHS SE land use data collected in 23 surveyed sites (18 in Orco and 5 in Chiusella river).

Data analysis

Try to relate four groups of RHS SE hydromorphological features, divided according to their spatial scale, to the catchment land cover data recorded ad different spatial scales with Principal Component Analysis (performed after gradient lenght estimation with a Detrended Correspondence Analysis) using CANOCO. Box and whisker plots (STATISTICA) of variables evidenced by multivariate analysis.

Results

Orco and Chiusella unstable river reaches can be evidenced by catchment scale characteristics, which resulted to be correlated to site scale (RHS SE scale) features.

Urban land use is correlated to straight, more stable river reaches and more stable substrate structure.

Land use categories recorded at catchment/subcatchment scale may influence microscale characteristics of current velocities and substrates.

Perspectives, Cause Effect Chain and Cause Effect Recovery chain

We hypothesized as possible future trends two alternative key hypothesis: an improve of morphology and biodiversity, due to the withdrawn of maize intensive cultivation from the floodplain and the subsequent reforestation of this areas, a hydromorphological deterioration as consequence of a more variable discharge regime and of a growing human intervenction. The urban development will directly affect hydromorphological characteristics from macro to microscale, making rivers more stable and straight. Hydromorphological features characteristic of unstable and curved river reaches, as sand deposits and point bars, could be greatly affected by human impact. The reduction of intervenction on fluvial morphology and the development of buffer strips in selected river reaches, could be usefull management measures in our study catchments.

3.3 Vecht catchment

Local scenarios expected

Climate*:* The two major climate parameters, temperature and precipitation were analysed over the last 100 years. Minimum, average and maximum temperature all show a positive trend from 1901 to 2003. Precipitation shows a positive trend over the last hundred years, though strongly fluctuating and not significant. Based on these data the precipitation increases with about 8.6 mm per year.

Source of climatic data: data collected by Dutch Royal Meteorological Institute (KNMI 2004) from the weather station 'De Bilt'; Dutch National Research Programme which commissioned the Hadley Centre for Climate Prediction and Research to provide them with a climate scenario for European weather in the period 1980-2100.

Discharge: Climate scenarios provided by Hadley Centre were used to predict future discharge events with the integrated model SIMGRO. Discharge will become somewhat more dynamic.

Land use: a withdrawal of agricultural activities from the floodplain expected. Furthermore, agricultural intensity will decrease in the catchment, at least with respect to nutrient input.

Collected data

Discharge data*:* collected in five different stream types. Evidencing the discharge patterns over the last 30 years in the different stream types and predictions on discharge extremity classes for the year 2100.

Land-use data*: s*election of four historical time periods (from 1900 to 2000) and establishing of the major land-use categories. Data extracted from historical Land-use maps: the area of heather and moorland peat dramatically decreased while the agricultural, urban and other land-use categories increased . The percentage of forest was stable over the whole period.

Hydromorphological data*:* expressed by the parameters of sinuosity, transversal profile shape and presence of weirs. Extraction of information on these parameters from digitalised topographic maps.

Data analysis

Use of information extracted from digitalised topographical maps: stream morphology parameters calculation with Arc View 3.3.

Results

Morphological features of the streams in the Vecht catchment show a degradation over the last hundred years. The total stream length was shortened, forty percent of the connected side-arms got lost and the number of oxbows increased around 1930 due to straightening of the major streams but decreased during the last period.

Perspectives, Cause Effect Chain and Cause Effect Recovery chain

In the Vecht catchment both hypotheses can become true:

hydromorphological deterioration through intensification of land-use or through a more variable discharge regime that results in habitat modification and losses;

a significant improvement for the withdrawn of human disturbances from the floodplain due to more frequent flood events or as a result of floods that generate a near-natural habitat structure, etc.

Major restoration measures that will be potentially successful in the catchment of the river Vecht are re-meandering on large scale or over a large strecht together with a change of land-use.

Conclusions

In conclusions two questions were answered:

1. What is the relation between climate - land-use - discharge - morphology in the Vecht catchment over the last 100 years?
    - hydrological change is documented only from 1950 on, and showed little change in dynamics after the seventies
    - morphological change took place in three phases (1900, 1930, 1960) and was not related to climate but to land-use
    - most changes took place in the first decennia of the 20th century
2. What is the effect of changes in discharge regime (caused by climate change) on the stream ecosystems?
    - discharge will become somewhat more dynamic which will affect both stream morphology and stream ecology.

3.4 Dinkel, Lahn, Eder catchments

Local scenarios expected

Climate data for time period 2070-2100 will be extracted from WP 1 climate scenarios. This data will be used to calculate discharge data for the Lahn and Eder catchments, using an existing rainfall / runoff model. Present discharge data and future discharges calculated by the rainfall / runoff model will be used to predict the present and future natural state of the streams in the study catchment on basis of empirical equations. These data will be used to assess, if the pressure exerted on the adjacent land use by the natural channel dynamics increases or decreases. The information on climate, discharge, and hydromorphological change will be used to develop land-use scenarios.

Collected data

Climate data: two sources for climate date: (a) a climatological atlas of Northrhine-Westphalia (1989), which contains monthly means of precipitation for each month, calculated from data from 1951-1980; scale 1:1.000.000, and (b) the journal "Weather Report", which has been published since 1953, displaying daily precipitation data and monthly means of the station net of the “Deutscher Wetterdienst” (German Meterological Organisation). No digital data are available.

Discharge data: available for 8 gauging sites, distributed throughout the catchments, generally measured daily by automatic devices and available as daily averages for time-periods of at least 10 years.

Hydromorphological data: Large hydromorphological data set compiled from regional authorities with field survey method of the “Länderarbeitsgemeinschaft Wasser” (LAWA).

Land-use data: ATKIS land-use data were used. A total of 192 different land-use categories were distinguished. These categories were aggregated to 10 categories within the scope of the analysis to distinguish between land-use categories, which differ in the magnitude of the land-use pressure “exerted” on the stream sections and to ease interpretation of the results. Three different “spheres of influence” were distinguished: (1) the near channel area (2) the valley bottom and (3) adjacent sections. The percentage-area covered by the land-use categories was calculated for the three “spheres of influence”.

Data analysis

In statistical analysis the hydromorphological parameters were used as dependant variables and the data on the percentage-area covered by the different land-use categories in the three “spheres of influence” were used as independent variables (using the software CANOCO). The statistical analysis was performed stream-type specific. Redundancy analysis (RDA) after a gradient determination with a DCA, was used. MLR was performed to quantify the relationship between the single hydromorphological parameters and the highly predictive land-use categories identified by the RDA. For each stream section, a measure of fit of the regression models was evaluated.

Results

The land-use most influential in the lower-mountainous area is the one on the valley bottom compared to the land-use adjacent to sections up- and downstream and the near-channel area. Differences increase with stream size, which is probably due to the fact that larger streams are considered as a hazard to land-uses far away from the channel. This supports the hypothesis that the relationship between land-use and hydromorphology is stream-size specific.

The measure of fit of the regression model seems too low to really predict / calculate the hydromorphological state based on land-use data. The results can be used to qualitatively describe the direction of change and to predict the future hydromorphological state in a semi-quantitative way for some hydromorphological parameters.

3.5 River Waldaist

Collected data

Lans use data: for the analysis of the land use within the catchment area a GIS data from Upper Austria (DORIS) was used. Used land use categories are: forests, different kinds of grassland and crop land.

Water Quality and pollution: The nutrient load is very low and the water quality shows mostly pristine conditions concerning organic pollution (OFENBÖCK 1997).

Data on the mobility of sandy substrates: preexisting data, not collected within this project, on bedload grading and mobility rates are available. Grain-size distribution curves for different sites, channel attributes and discharge data used to calculate estimations for transport rates and mobility of bedload in relation to discharge of the tributaries. It is demonstrated that the huge amount of mobile sandy substrates is mostly caused by drainage measures in coniferous forests.

Data analysis

The results of the analysis of the land use (GIS) data were correlated with the calculated bedload transport rates in proportion to discharge.

Results

The correlation indicates a relationship between land use and the mobility of sandy substrates in the catchment area. Drainage measures in the catchment are the major resource for siltation processes.

Perspectives, Cause Effect Chain and Cause Effect Recovery chain

Focus on siltation, habitat composition and sediment transport rates changes through change of land-use, change in the species composition of trees, change in discharge regime.

Experiences for restoration measures (e.g. sand traps) from the River Lutter in Germany performed to reduce the input of fine substrates.

3.5 River Neajlov

Local scenarios expected

Climate: The climatic/discharge scenarios will be obtained through mathematical modelling of hydrological processes at the catchment scale, based on data from climatic scenarios developed in consortium.

Dicharge: the climatic changes are expected to induce two main possible scenarios in the selected catchment: a decrease of river discharges accompanied by a decrease of groundwater table, or an increase of river flows and consequently of groundwater table.

Land use: the decrease of groundwater table will induce the reduction of wetland zones and changes in land use will occur (more land will be used for agriculture). These kinds of changes occurred in the last decades in our catchment due to hydrotechical works in its south part. On the contrary, the groundwater table increase will be accompanied by an extention of wetland zones.

Collected data

Climate data: rain data recorded in one meteorological station from 1994 up to the present, with a daily frequency. Other climatic data available are solar radiation, daily air Tmed, Tmin,Tmax and soil Tmed, Tmin, Tmax.

Hydrological data: recorded in 7 stations for long-time measurements, usually with monthly measurements, higher number for shorter periods. Focus on data from 3 monitoring stations, with a daily frequrncy record located on Neajlov River. Time series available for at least 20 years; at this moment the data for the last 10 years.

Land use data: Corine landcover map.

Hydromorphological data: description of hydromorphological characteristics at the local scale (selected points) from maps 1:5000. Information from literature have been also gathered.

Data analysis

In order to establish relations between land-use/discharge we intend to use both regression, pattern and multivariate analysis

Results

To be completed.

Perspectives, Cause Effect Chain and Cause Effect Recovery chain

In the last decades, the dominant process was the modification and losses of habitats due to intensification of land use and we expect this will better reflect the interaction climate/discharge.

Stressing the importance of riparian structures in both biodiversity conservation, and in controlling the nutrient fluxes from agricultural landscapes. The reconstruction of buffer zones considered as one of the most important management measures for improving river morphology**.**

3.7 *The Emå Catchment*

Local scenarios expected

Discharge: according to the climate scenarios for the south-eastern Sweden, where Emån is situated, there will be less frequent floods, and less total discharge in the rivers. More of the water will come into the system during winter and less during summer.

Source of information: literature.

Information reported on: geography, history, water quality, geomorphology.

Collected data

Climate data: mean January and July temperature, mean yearly precipitation, growing season.

Discharge data:. Mean, lowest and highest discharge value from 1926-1975. Monthly discharge between 1996 and 2003.

Land-use data

Stream morphology: larger streams/rivers within the Emå catchment mapped using the biotope inventory method (Swedish Environmental Protection Agency, 2003). A total of 1624 river stretches were inventoried. The stream velocity and form of the river of each stretch were divided into categories.

Data analysis

The relationship between in-stream variables were analysed using Principal Components Analysis (PCA) and the relation to the near-stream zone (riparian vegetation), referred to an area of 30 m along each bank and to a 200 meter wide zone on each side of the stream, were analyzed using Redundancy Analysis (RDA), in the program CANOCO for windows, version 4.5.

Results

The slow flowing sections are the most abundant, the fast flowing water are the rarest. The sinuous form is the most common, followed by the straight stretches and meandering parts. Along the first axis of the PCA there was a gradient of substratum types and in-stream vegetation: from detritus, sand, clay with emergent and floating vegetation to cobbles, blocks, and rocks with mosses and filamentous algae. The second axis was more difficult to interpret. Among the 11 explanatory variables chosen in a RDA forward selection procedure, the most important of these variables were shading along the banks of the river or stream, followed by the mean depth and whether of not the stream were meandering.

3.8 The Becva catchment

Local scenarios expected

Climatic/discharge/land use models used: Construction of the climate scenarios for the Czech Republic with 2 models (GCM) corresponding with the climate of Central Europe (SRES B1, SRES A2), referred to a time horizon of 2050. Application of the BILAN, CLIRUN and SAC-SMA models.

The simulations demonstrated that the runoff changes are closely related to the change of the annual precipitation pattern. The annual distribution of the air temperature should be taken into account. The impact of climate change would be more severe in low flow periods and in catchments with low capacity for natural groundwater accumulation. The flysh geology which dominates in the model catchment is associated with rapid runoff of rainfall. This would emphasize effect of extreme floods (in cold period), summer-autumn droughts and more frequent flow extremes, phenomena being predicted as a consequences of climate changes

Climatic/discharge/land use scenarios: precipitation decrease in summer and increase in winter or in October. Possible land use scenarios in the model catchment are: changes in riparian zone – extension/restoration of buffer zone of river, predominantly replacing cropland areas.

Problems for the catchment.

Combining restoration and flood protection activities. There is lack of information on aquatic biota. A serious problem could be the realization of the Oder-Elbe-Danube navigation canal, because studied segment of the Becva River is a part of planned course.

Collected data

Climatic data: Rain data available are precipitation records (day amount) from 3 stations, referred to 30 years with day amount frequency. Other climatic data available are air temperature (day average calculated from 3 values) from 4 stations.

Discharge data: 4 stations are used for the discharge measurement. Water level is recorded continuously: day average of discharge will be available since 1978.

Land use data: Corine Land Cover vector shapefile, orthophotos, stream network and subcatchments shapefiles, digitalized map of surface water regions (1:500000). Information provided by the Ministry of Environment, the Water Research Institute TGM and the Land Survey Office. A 600 m wide buffer centered to the axis original channel was delineated along a 61 km long river segment, and it was devided on the 1 km-long buffer sections. The proportion of Corine land cover categories was determined within individual buffer sections. The categories were merged into categories used in AQEM project.

Hydromorphological data: The results of specific hydromorphological analyses are available for the studied sites Osek and Cernotin from bibliographic source (Sindlar, 2000). The width of riparian vegetation was recorded from aerial photos in interval of 100 m for studied stretches and in interval 1 km within 42 km long section of the Becva River. Additional hydromorphological surveys are planned for year 2005 linked to biota surveys.

Data analysis

The initial analyses focused on existing data based on aerial photos, GIS layers, comparison with historical information. Complex evaluation will be done after collection additional data from field surveys at pilot stretches. Futher analyses will be based on the smaller scale (stretch, transects, habitats) characteristics gathered in the linkage to biological data (2005, 2006).

Local problems

Geological, climate and hydrological characteristics of the Becva River catchment caused periodical flooding of areas around the water course. The flood protection of settlements and cropland by constructing the embankment changed the original character of the meandering and anastomosing channel. The channel cross-section was modified to a trapezoidal shape.

Results

Catastrophic floods altered the fluvial topography of the riverine landscape. The dominant processes in low-slope gravel rivers are the lateral erosion broadening the channel and the redistribution of sediments. After the decision to maintain river stretches in the “destroyed“ state it was found that some natural hydromorphological features were restored to the state documented from the period before regulation.

Perspectives for the selected study catchment.

The protection based on status of National Nature Reserve is planned for the site Osek. Some other sites of comparable value could be degraded by contruction of polders or reservoirs as potential solution of flood protection.

Cause Effect Chain expected

The withdrawn of human disturbance from the floodplain following catastrophic floods was realized in the Becva River catchment at 5 segments.

Management measures

The feature contributing to improved hydromorphology are wider and not uniform channel, restoration of riparian vegetation. The even wider corridor would be needed to reserve for errosional-depositional processes forming channel in near natural way. The artificially scoured channel bottom is also serious problem for the restoration of floodplain. Comparing aerial photos before and after floods is obvious increasing spatial heterogeneity of alluvial habitats, higher variability of channel width. The succesion of vegetation on the newly formed grevel bars is documented by botanical studies .

4 CONCLUSIVE GENERAL REMARKS

The answers to the proposed questionnaire and the contributions inserted in this report evidenced some general remarks on scenarios adopted, collected data, data analysis methods, preliminar results, cause-effect chains expected and on recovery measures which could be adopted in the study catchments. These general remarks should be of help to better our understanding of existing data and to stress the importance of collecting comparable data across Europe. Comparable data across Europe will allow the sudy of stream ecosystems at different spatial scales: from regional (ecoregion) to microhabitat scale. According to hierarchy theory, physical and biological variables on a small spatial scale are influenced by variables on larger spatial scales (Allen & Starr, 1982). Several authors stressed the importance of a combined understanding of both local and large scale environmental variables in stream ecosystems, confirming the hierarchy theory (Weigel et al., 2003; Sandin & Johnson, 2004; Townsend et al., 2004). In such studies one caveat in assessing the importance of spatial scale is the large amount of data which are necessary to study the range of spatial scales encountered. Moreover the scale at which a system is observed must be considered when comparing the factors influencing the ecosystem (e.g. Frisell et al., 1986). It is therefore evident as more comparable data across Europe are needed to better understand the relative influence of environmental variables at different spatial scales, which is an important step towards improved knowledge of factors that are important in influencing stream ecosystems and to predict how climate and human induced alterations will affect such ecosystems.

Finally the preliminary results have been interpretated under a biological perspective which will be examined in Tasks focused on biota: some research arguments for WP 2, Task 2 are proposed.

Climatic/discharge scenarios

Almost all partners use scenarios extracted from literature and from other projects focused on climate changes. The information on climate scenarios from WP 1 has not been used in Task 1.1 final report writing because such information became available at the end of Task 1.1. Climatic/hydrologic scenarios are rather similar among Task 1.1 partners: there is a general agreement on climatic/hydrologic scenarios expected. An increase in temperature, a decrease in summer and an increase in autumn-winter precipitations, an increase of extreme daily precipitation, are generally expected. Consequently, discharge will show a more dynamic regime, due to increases in extreme daily precipitation and in severity of droughts.

Land use scenarios

The information on climate, discharge, and hydromorphological change should be used as starting point to develop land use scenarios. Because of the lack of information on the combined effects of climate-discharge-hydromorphology in the selected catchments, land use scenarios adopted by Task 1.1 partners are mainly based on the actual land use and on historical recostruction of its general trend, when available. According to this, land use scenarios differ between different partners, with a common statement concerning the increase of urbanisation, which will slightly increase flood risk in the next years, and on the fact that agricultural land use will be influenced by climatic/hydrologic changes. On the contrary, many uncertainties on land use scenarios expected exist; in rivers riparian zone, both an extension/restoration of the buffer zone both habitat modification and losses are expected.

Collected data

Climatic/hydrologic/land use data are available for all selected study catchments. Time series are often available for Climatic/hydrologic data (4-40 years): a problem could be linked to data format which often is not a digital format (only cartaceous data are available). Sometimes land/floodplain use hystorical data are available too: hystorical land use recostructions extracted from digitalized hystorical maps.

Discharge data usually are available as monthly averages measurements, climatic data as daily precipitation amount and air temperature. Most common land use data source is Corine Land Cover; ATKIS, DORIS and data from photointerpretation of aerial photos are also available.

Hydromorphologycal data sources usually are referred to 1993-present day situation and are different among Task 1.1 partners. To reconstruct hystorical trend of stream morphology parameters ALTERRA used digitalised topographical maps and the program Arc View. SLU used the biotope data from the Local County

Board of Jönköping. With the aim to collect comparable data, a list of hydromorphological features and existing survey methods has been compiled by UDE and CNR-IRSA and circulated among Task 1.1 partners (Annex 2). River Habitat Survey (RHS and RHS SE, used by NERC and CNR-IRSA) and LAWA (used by UDE) are the most common used methods. Digital Elevation Model and Ökomorphologische Zustandtskartierung are the other hydromorphological data sources.

Data analysis

Two partners (ALTERRA and Mas-Univ) analyses focus on historical development of interactions between hydromorphology and landuse. The approach aims to reconstruct the historical trend from digitalised topographic maps. ALTERRA study focuses on the time period of 1900-2000, distinguishing 6 main land use categories. Mas-Univ started to analise existing data based on aerial photos, GIS layers, comparison with historical information. The actual percentage of Corine land cover categories was determined and then were merged into AQEM land use categories.

BOKU data analysis was focused on siltation. The results of the analysis of the land use GIS data (DORIS) have been correlated to the calculated bedload transport rates, in proportion to discharge and channel attributes. Siltation resulted to be mostly caused by drainage measures in coniferous forests. The land use categories used for the analysis were the most important in the area (forests, different kinds of grassland and crop land).

Four partners performed a multivariate ordination (CNR-IRSA, NERC, SLU and UDE) inserting land use data as independent variables and hydromorphological data as dependend variables. To perform the analysis three of them used CANOCO. Beside this common starting point, the ordination analysis have been performed in different ways by Task 1.1 partners.

NERC and UDE used a Direct Gradient analysis (RDA), CNR-IRSA used an Indirect Gradient Analysis (PCA) and SLU performed both a Direct both an Indirect Gradient Analysis.

NERC and UDE performed the RDA with land use categories aggregated to EUNIS Level 1 and with 10 general categories, respectively. CNR-IRSA used an Indirect Gradient Analysis (PCA), with both not aggregated (Level 3, Corine) and aggregated (Level 1, Corine) land use categories.

UDE considered the direct gradient analysis as the most indicated method to interpret land use-hydromorphology interactions and to process the large amount of available data from different stream types. The indirect gradient analysis has been used by CNR-IRSA according to a smaller data set and to the consideration that the existing hydromorphological gradient could be related to variables not inserted in the analysis. SLU performed a PCA on in-stream variables and a RDA to relate in-stream variables with the near-stream zone (riparian vegetation). In the Direct Gradient Analysis, the explanatory variables were chosen in a RDA forward selection procedure, where variables explaining > 1.5% of the total explained variation (TEV) and being statistically significant ($p < 0.001$) were included.

NERC used as dependent variables the hydromorphological information collected by River Habitat Survey combined into Habitat Quality Scores presented at three nested levels.

UDE performed a MLR to measure the fit of the regression models for each stream section, CNR-IRSA used box and Whiskers Plots to separate sections with different hydromorphological characteristics according to the highly predictive land-use categories identified by the PCA.

Results

The partners which used the historical recostruction evidenced as morphological features show a degradation over the last hundred years and as catastrophic floods may alter the fluvial topography of the riverine landscape. The historical recostruction is the approach which is best suited to predict the effects of future climatic-land use changes on hydromorphology. The predictions of future trends based on historical reconstructions of climatic-land use-hydromorphology interactions should be more reliable than predictions based on shorter time scales observations. Often the main obstacle to overcome in this approach is data availability: historical time series often are not available or are available not in a digital format. This is particular evident with land use data: hystorical land use changes can be reconstructed only after digitalization of topographical maps referred to different historical periods.

The analysis performed by BOKU evidence a relationship between drainage measures and the mobility of sandy substrates in the catchment area and UDE evidenced a stream-size specific relationship between land-use and hydromorphology. These results clearly demonstrate the importance of local characterstics: different stream types may respond in a quite different way to climate-land use changes.

The multivariate analysis evidenced as the land use data often cannot be used to really predict / calculate the hydromorphological state. The land use-hydromorphological variables relationships can be used to qualitatively describe the direction of change and to predict the future hydromorphological state in a semi-quantitative way for some hydromorphological parameters.

Under this perspective, CNR-IRSA evidenced as catchment scale land use may be related to depositional/erosional activity at site scale and may influence microscale characteristics of current velocities and substrates. Urban land use resulted to be correlated to straight, more stable river reaches and more stable substrate structure.

SLU results evidenced as in Emå catchment, where 74% of area is covered by forest, the slow flowing sections were clearly the most abundant, the fast flowing water were the rarest and commonly the river form is "sinuous". SLU ordination analysis underlines the importance of in-stream meso/microhabitat characteristics of substrate/channel vegetation and as the most important explanatory variables were shading along the banks of the river or stream, the mean depth and whether of not the stream were meandering. NERC analysis, focused on the local area spatial extent, confirm the importance of in-stream vegetation, evidencing its association with land use. Bankside vegetation, bank and channel features, riverbed substrate and flow diversity are other hydromorphological parameters which seemed to be affected by land use in the local area around a site. According to this results, any change to climate that caused a land use change could lead to a shift in the hydromorphological parameters evidenced by the analysis.

Cause Effect Chain and Cause Effect Recovery chain

Both the two alternative CEC are expected among WP2, Task 1.1 partners. It is therefore evident the existing incertanty when studying the characteristics and responses of fluvial ecosystems to the complex interactions existing between climate-landuse-hydrology-hydromorphology and the importance of every single catchment characteristics in influencing the expected effects.

Single catchments characteristics must be considered for management measures decision too: for example the use of sand traps where siltation problems are present. The modelisation of cause-effect-chains and cause-effect recovery chains at single catchment scale is a very important step because in the future, the information extracted from the local approach could be used on a broader spatial scale.

Most partners evidenced the importance of riparian structures in both biodiversity conservation, and in controlling the nutrient fluxes from agricultural landscapes. According to this, an indicated management measure for improving river morphology is, for example, the restoration of riparian vegetation.

Other restoration measures evidenced are re-meandering on large scale or over a large strecht, the reconstruction of buffer zones, the decision to maintain river stretches in the "destroyed" state, wider and not uniform channels, the reduction of intervection on stream morphology, together with a change of land-use.

The experience on recovery measures in the study catchments evidences as the general tendencies should be towards (Verdonschot & Nijboer, 2002):

- ✓ an increase in the use of a combination of measures;
- ✓ the use of the hierarchically most important measure;
- ✓ the inclusion of the relation between catchment and stream reaches, necessary to improve the stream ecosystem.

Biological perspectives

Land use changes at catchment scale influence streams through changes in nutrient loading, solar energy flux, hydrology, sediment inputs, organic matter inputs, decomposition rates and subsequently have an impact on biotic assemblages. Stream macroinvertebrates are commonly used as indicators of environmental conditions because they respond integratively to influences at multiple spatial scales through properties of both physical habitat and water chemistry.

Within WP 2, Task 2 is focused on hydromorphological changes and aquatic and riparian biota response. Stream, riparian and marginal wetland fauna will be examined at the habitat scale to make clear the responses of biota to hydrological and morphological structures and variation. The results will be used to assess the impact of future climate and land use change on biota.

Recently, it has been shown as in Central European streams physical habitat degradation appears to be the most important threat to aquatic and riparian biota (Lorenz et al., 2004). In South Europe, hydrological and related morphological constraints are central in structuring biological communities and ecosystem functioning. Changes in flow regime associated with high climatic variability is likely to be an important process affecting benthic community (e.g. Langton & Casas, 1999), in particular streams in Mediterranean-type climates have been proposed to be comparatively more flood prone than streams in humid temperate climates (e.g., King et al., 1987). According to climate/hydrologic scenarios expected it should be of interest the study of the effect of floods and droughts on benthic community in the selected catchments. To explain the observed responses of biota community composition to such extreme events, factors as resilience properties possessed by different taxa, regional species richness (beta diversity) and taxa dispersal ability should be considered.

A particular problem could be related to more intense droughts, which resulted to have a major impact on biota than floods, possibly by altering habitat availability and the intensity of biotic interactions as surface stream volume shrank (Boulton et al., 1992).

Hydromorphological state affects the benthic community through a multitude of factors, e.g. flow conditions, habitat degradation and availability, temperature profiles, detritus processing, etc., all acting at different spatial scales. It is therefore evident the importance to approach this study at different spatial and temporal scales.

According to the preliminary results of Task 1.1, several issues could be of interest in Task 2, e.g.:

- the impact of hydromorphological stress on aquatic insects, and test whether the effects of this stressor differed in different habitat types as riffles, pools, and banks.

- the relationship between aquatic community structure, species richness, colonisation strategies, *r* and *k* strategy, and the hydromorphological state in terms of river stability/instability (macroscale-mesoscale).

- the invertebrate community response to substrate stability/instability (meso-microscale). The focus, when possible, might be on invertebrates of Exposed Riverine Sediments (Eyre & Lott, 1997) as well. More stable conditions, with vegetated substrates, richest in habitat types and food resources, should be analysed and compared to unstable conditions, with not vegetated substrates, poorest in habitat types and food resources.

As underlined by many authors, the surroundings areas of rivers and their land use affect the riparian zone, whose state and function can influence lotic macroinvertebrates. As a consequence, another focus might be devoted to:

- the study of riparian zones as terrestrial-wetland ecotones and how they can affect both the adjacent benthic and terrestrian communities in relation to land use and river reach stability/instability.

Finally, this considerations could be extended to a stream typolgy perspective, evidencing the following question:

- are there any differences between stream types?

At last, according to the Water Framework Directive the evaluation of the effects of hydromorphological features on biotic communities will be a very important step for the development of scientifically sound assessment methods.

5 BIBLIOGRAPHIC REFERENCES

5.1 Climatic/Discharge scenarios

Andreasson J., S. Bergstrom, B. Carlsson, L.P. Graham & G. Lindstrom, 2004. Hydrological change – climatic change impact simulations for Sweden. *Ambio* 33 (3-4): 228-234.

Arnell N.W., 1999. The effect of climate on hydrological regimes in Europe: a continental perspective. *Global Environmental Change*, 9: 5-23.

Brunetti M., L. Buffoni, M. Maugeri & T. Nanni, 2000. Precipitation intensity trends in northern Italy. *International Journal of Climatology*, 20: 1017-1031.

Delworth T. L. & S. Manabe, 1988. The influence of potential evaporation on the variabilities of simulated soil wetness and climate. *Journal of Climate*, 1: 523-546.

Frei C. & C. Schär, 1998. A precipitation climatology of the Alps from high-resolution rain-gauge observations. *International Journal of Climatology*, 18: 873-900.

Frei C., J. Hesselbjerg Christenses, M. Dequé, D. Jacob, R. G. Jones & P. L. Vidale, 2003. Daily precipitation statistics in regional climate models: evaluation and intercomparison for the European Alps. *Journal of Geophisical research*, 108 (D3), 4124, doi:10.1029/2002JD002287.

Hladny J. et al., 1997. Impacts of a Potential Climate Change on Hydrology and Water Resources in the Czech Republic. Praha 1997. 135 p.

Hulme M., G.J. Jenkins, X. Lu, J.R. Turnpenny, T.D. Mitchell, R.G. Jones, J. Lowe, J.M. Murphy, D. Hassell, P. Boorman, R. McDonald & S. Hill, 2002. *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report*. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

Kalvova J. et al., 1996. Climate Change Scenarios for the Czech Republic. Praha 1996. 101 p.

Nitrogen **Co**ntrol by **La**ndscape **S**tructures in Agricultural Environments – (NICOLAS) - EVVA-CT97-0395 and **E**uropean **V**aluation and **A**ssessment too**L**s s**U**pporting **W**etland **E**cosystem legisla**T**ion (EVALUWET) – EVK1 - CT - 2000 - 00070.

Räisänen J., 2002. CO2-induced changes in interannual temperature and precipitation variability in 19 CMIP2 experiments. *Journal of Climate*, 15: 2395-2411.

Räisänen J., U. Hansson, A. Ullerstig, R. Döscher, L. P. Graham, C. Jones, M. Meier, P. Samuelsson & U.Willén, 2003. *GCM driven simulations of recent and future climate with the Rossby Centre coupled atmosphere – Baltic Sea regional climate model RCAO*. SWECLIM programme and EU PRUDENCE project, report number: RMK No. 101, January 2003, 61 pp.

Schmidli J., C. Schmutz, C. Frei, H. Wanner & C. Schar, 2002. Mesoscale precipitation variabilty in the region of the european Alps during the 20th century. *International Journal of Climatology,* 22: 1049-1074.

Tett S. F. B., T. C. Johns & J. F. B. Mitchell, 1997. Global and regional variability in a coupled AOGCM. *Climate Dynamics*, 13: 303-323.

van Walsum P.E.V., P.F.M. Verdonschot & J. Runhaar (eds.) 2002. *Effects of climate and land-use change on lowland stream ecosystems. Alterra-report 523, IS*SN 1566-7197. 200 pp.

Verweij W. & Viner D., 2001. *Description of the default climate scenario for impact projects in NRP-II.* Dutch National Programme on Global Air Pollution and Climate Change. Report no. 410 200 058. RIVM, Bilthoven.

Viner D. & Hulme M., 1998. *The climate impacts LINK project: Applying results from the Hadley Centre's climate change experiments for climate change impacts assessments*. CRU, UEA, Norwich, United Kingdom.

5.2 Land use

Davies M. B. & D. B. Botkin, 1985. Sensitivity of cool-temperate forest and their fossil pollen record to rapid temperature change. *Quaternary research,* 23: 327-340.

Duce P., D. Spano, A. Motroni & S. Canu, 2003. *Rischio climatico per l'agricoltura in ambiente mediterraneo*. Atti Workshop "CLIMAGRI – Cambiamenti Climatici e Agricoltura", Cagliari, 16-17 gennaio 2003.

Gumiero B. & G. Salmoiraghi, 1997. The relationship between land use, river bank quality and lotic macroinvertebrate community. *Buffer zones: Their processes and potential in Water Protection*. N. E. Haycock, T.P. Burt, K.W.T. Goulding and G. Pinay (Ed.). Quest Evironmental.

Hossell J.E., P.J.Jones, J.S. Marsh, M.L. Parry, T. Rehman & R.B. Tranter, 1996. The Likely Effect of Climate Change on Agricultural Land Use in England and Wales. *Geoforum*, 27 (2): 149-157.

Killingseder Hans-Peter, 1998. Geschiebe und Feststofftransport im Einzugsgebiet der Waldaist.

Miller C. & D. L. Urban, 1999. Forest Pattern, Fire, and Climatic Change in the Sierra Nevada. *Ecosystems*, 2: 76-87.

Ofenböck T. , 1997, 1998. Flussperlmuschel-Schutzprojekt Oberösterreich (FLUP) - Pilotstudie Waldaist.

Runhaar J., P.C. Jansen, H. Timmermans, F.P. Sival & W.C. Knol, 2003. Historische waterhuishouding en historisch grondgebruik in het waterschap Regge en Dinkel. Alterra-rapport 801.

5.3 Hydromorphology

Allen T.H.F. & T.B. Starr, 1982. *Hierarchy: perspectives for ecological complexity*. Chicago of University Press, Chicago, Chicago USA.

Boulton A.J., C.G. Peterson, N.B. Grimm & S.G. Fisher, 1992. Stability of an aquatic macroinvertebrate community in a multiyear hydrologic disturbance regime. *Ecology*, 73 (6): 2192-2207.

Buffagni A. & J. L. Kemp, 2002. Looking beyond the shores of the United Kingdom: addenda for the application of River Habitat Survey in Southern European rivers. *Journal of Limnology*, 61(2): 199-214.

Buffagni A., S. Erba, D. Armanini, D. De Martini & S. Somarè, 2004. Hydromorphology and the lentic-lotic character of Mediterranean rivers: River Habitat Survey and LRD descriptor. In *Ecological Classification and Lentic-Lotic Character in Mediterranean Rivers*, Quaderni, 122, CNR-ISTITUTO DI RICERCA SULLE ACQUE, ROMA, 41-63 p.

Church M. A., D. G. McLean & J. F. Wolcott, 1987. River bed gravels: Sampling and analysis. in: C. R. Thorne, J. C. Bathurst, R. D. Hey. *Sediment transport in gravel-bed rivers*. John Wiley & Sons, Chichester, 789.

Environment Agency, 1997. *River Habitat Survey, 1997 field survey guidance manual*. Environment Agency.

Environment Agency, 2003. *River Habitet Survey in Britain and Ireland - Field Survey Guidance Manual: 2003 Version*. Warrington, Cheshire WA4 1HG.

Eyre M.D. & D.A. Lott, 1997. *Invertebrates of Exposed Riverine Sediments*. Entomological Monitoring Services (EMS). R&D Technical Report W11.Environment Agency. 93 p.

Frisell C.A., W.L. Liss, C.E. Warren & M.D. Hurley, 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. *Environmental Management*, 10:199-214.

Jeffers J.N.R., 1998. The statistical basis of sampling strategies for rivers: an example using River Habitat Survey. *Aquatic Conservation-Marine and Freshwater Ecosys-tems*, 8: 529-540.

Kellerhalls R & M. Church, 1989. The morphology of large rivers: characterization and management. In: Dodge DP (ed). Proceedings of the International Large Rivers Symposium. *Canadian Special Publication of Fisheries and Aquatic Sciences*. 106: 31-48.

King J.M., M.P. Henshallhoward, J.A. Day & B.R. Davies, 1987. Leaf-pack dynamics in a southern african mountain stream. *Freshwater Biology*. 18 (2): 325-340.

Knighton D., 1998. *Fluvial forms and processes*. Oxford University Press, New York, 383 p.

Langton P.H. & J. Casas, 1999. Changes in chironomid assemblage composition in two Mediterranean mountain streams over a period of extreme hydrological conditions. *Hydrobiologia*, 390: 37-49.

Lorenz A., D. Hering, C.K. Feld & P. Rolauffs, 2004. A new method for assessing the impact of hydromorphological degradation on the macroinvertebrate fauna of five German stream types. *Hydrobiologia*, 516: 107-127.

Raven P.J., N.T.H. Holmes, F.H. Dawson & M. Everard, 1998a. Quality assessment using River Habitat Survey data. *Aquatic Conservation-Marine and Freshwater Eco-systems*, 8: 477-499.

Raven P.J., N.T.H. Holmes, F.H. Dawson, P.J.A. Fox, M. Everard, I.R. Fozzard, & K.J. Rouen. 1998b. *River Habitat Quality: the character of freshwater streams and rivers in the UK and Isle of Man*. Rep. No. Report No. 2. Environment Agency.

Raven P. J., Homes, N. T. H., Charrier, P., Dawson, F. H., Naura, M., Boon, P. J. 2002. Towards a harmonized approach for hydromorpological assessment of rivers in Europe: a qualitative comparison of three survey methods. *Aquatic Conservation: Marine and Freshwater Ecosystems* (12), 405-424.

Sandin L. & R.K. Johnson, 2004. Local, landscape and regional factors structuring benthic macroinvertebrate assemblages in Swedish streams. *Landscape Ecology*, 19: 501-514.

Townsend C., B.J. Downes, K. Peacock & C.J. Arbuckle, 2004. Scale and the detection of land-use effects on morphology, vegetation and macroinvertebrate communities of grassland streams. *Freshwater Biology*, 49: 448-462.

Weigel B.M., L. Wang, P.W. Rasmussen, J.T. Butcher, P.M. Stewart, T.P. Simon & M.J. Wiley, 2003. Relative influence of variables at multiple spatial scales on stream macroinvertebrates in the Northern Lakes and Forest ecoregion, U.S.A. *Freshwater Biology*, 48: 1440-1461.

5.4 Cause Effect Chains and Recovery measures

Beechie T. & S. Bolton, 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest Watersheds. *Fisheries*, 24: 6-15.

Bisson P. A., S. M. Wondzell, G. H. Reeves & S. V.Gregory, 2003. Trends in using wood to restore aquatic habitats and fish communities in western North American rivers. in: S. Gregory, K.

Boyer L. & A. M. Gurnell. The ecology and management of wood in world rivers. American Fisheries Society, Symposium 37, Bethesda, Maryland, 391-406.

Driessen J.M.C., P.F.M Verdonschot. & J.A. Schot, 1998. Stream rehabilitation in The Netherlands: present status and future developments. In: H.O. Hansen & B.L. Madsen, River Restoration '96, Session lectures proceedings. International Conference arranged by the European Centre for River Restoration: 254-260. National Environmental Research Institute, Denmark.

Frissell C. A. & R. K. Nawa, 1992. Incidence and causes of physical failure of artificial habitat structures in streams of Western Oregon and Washington. *North American Journal of Fisheries Management* (12), 182-197.

Kail J., 2003. Influence of large woody debris on the morphology of six central European streams. *Geomorphology* (51), 207-223.

Kauffman J. B., R. L.Beschta, N. Otting, & D. Lytjen, 1997. An ecological perspective of riparian and stream restoration in the Western United States. Fisheries (22), 12-24.

Kondolf G. M., 2000. Some suggested guidelines for geomorphic aspects of anadromous salmonid habitat restoration proposals. *Restoration Ecology* (8), 48-56.

Roni P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock & G. R. Pess, 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *North American Journal of Fisheries Management* (22), 1-20.

Roper B. B., D. Konnoff, D. Heller & K. Wieman, 1998. Durability of Pacific Northwest instream structures following floods. *North American Journal of Fisheries Management* (18), 686-693.

Verdonschot P.F.M. & R.C. Nijboer, 2002. Towards a decision support system for stream restoration in the Netherlands: an overview of restoration projects and future needs. *Hydrobiologia*, 478, 131-148.

Wright J.F., R.T. Clarke, R.J.M.Gunn, J.M. Winder, N.T. Kneebone & J. Davy-Bowker, 2003. Response of the flora and macroinvertebrate fauna of a chalk stream site to changes in management. *Freshwater Biology*, 48, 894-911.

Wright J.F., R.T. Clarke, R.J.M. Gunn, N.T. Kneebone & J. Davy-Bowker, 2004. Impact of major changes in flow regime on the macroinvertebrate assemblages of four chalk stream sites, 1997-2001. *River Research and Applications*, 20 (7)

ANNEXES

ANNEX 1: WP 2, Task 1.1 catchment data questionnaire
ANNEX 2: WP 2, Task 1.1 hydromorphological features document
ANNEX 3: Task 1.1 Partners details and e-mail addresses

ANNEX 1: WP 2, Task 1.1 catchment data questionnaire

Euro-limpacs

EC CONTRACT NR. GOCE-CT-2003-505540

WP2 : CLIMATE –HYDROMORPHOLOGY INTERACTIONS

Task 1 Effects of climate/land use changes on hydro(morpho)logy

Subtask 1.1 Rivers : Environmental data collection and analyses

Task Leader:	Andrea Buffagni (CNR), buffagni@irsa.rm.cnr.it
Partners:	ALTERRA, BOKU, NERC, CNR, MasUniv, SLU, UDE, UNIBUC-ECO
Period:	month 1-9

Questionnaire reference person: Carlotta Casalegno (CNR), casalegno@irsa.rm.cnr.it

Catchment data questionnaire

This questionnaire has been compiled with the aim to collect general information on different partners' work plan adopted in Euro-Limpacs, WP2, Task 1.1. The questions proposed mainly focus on which scenarios (climatic, land use) each partner will use and which will be the selected approach to study the effects of climate/land use changes on hydrology and hydromorphology in the selected catchments. Moreover we are interested on which results different partners are expecting. The information collected with this questionnaire, giving an overview of the current situation in Task 1.1, will be of great help in the final report writing. In particular, the overview of the data being collected by different partners will be used to picture the general situation and eventually to compare different approaches used to study the relations between land use/discharge alterations and hydromorphology.

Partner details for the Questionnaire

Partner	Contact person	e-mail

Model catchment

Please check/compile the following table. Catchment size is intended at the most downstream river site included in the Eurolimpacs WP 2 activities. Latitude and longitude can be referred to the same river site.

catchment	*country*	Catchment area (Km^2)	latitude (degrees)	longitude (degrees)	Location

Questions

1 Give a short description of local climatic/discharge alteration scenarios expected in your model catchment.
2 Which time range (years) are you going to consider for the climatic scenario (e.g. 2070, 2100, others)?
3 Please, indicate the bibliographic references from where you have extracted climatic/ discharge alteration scenarios.
4 Give a short description of possible land use scenarios in your model catchment.
5 Indicate the bibliographic references from where you have extracted your land use scenarios.

6 In your model catchment, how many stations are used for the discharge misuration?
7 Where are them positioned (e.g. at the closing section of the catchment, close to the source of the river, in the middle of the catchment)?
8 How long is the discharge time series? Since when discharge data are available?
9 Which is the frequency of discharge measures?

10 For your study catchment, which rain data are/will be available (rain, number of precipitation days, extreme daily precipitation, snow cover, runoff, etc.)?
11 From how many stations (ca) are rain data available in the catchment?
12 How long will your rain data series be (ca)?
13 Which is the observation frequency of rain data collection?

14 Which other climatic data are available from the model catchment (air temperature, diurnal temperature range, Tmin, Tmax, evaporation, soil moisture)?

15 Which kind of data analysis you expect to use to establish relations between land-use/discharge and hydromorphology (e.g. regression, pattern and multivariate analysis)?

16 Have you ever used a hydromorphological model? If yes, which one?
17 If yes, at what spatial scale have you used such hydromorphological model?
18 Have you ever used hydromorphological models to study erosional/depositional phenomena in rivers?
19 Would you recommend to use such model(s) in WP 2 to infer on habitat availability and pattern changes following land use and climate variations (if model is appropriate)?

20 Which hypothetical Cause Effect Chain you expect to better reflect the interactions between climate change and river hydromorphology through land use/discharge alterations in your model catchment (hydromorphological deterioration through intensification of land-use or through a more variable discharge regime that results in habitat modification and losses; or, alternatively, a significant improvement for the withdrawn of human disturbances from the floodplain due to more frequent flood events or as a result of floods that generate a near-natural habitat structure, etc.)?

21 Have you any information on which management measures might be useful in improving channel morphology (Cause Effect Recovery chain) in your catchment (no reconstruction of regulation works destroyed by flooding, revitalisation of buffer strip zone, etc), e.g. from existing studies?

22 Comments and suggestions

ANNEX 2: WP 2, Task 1.1 hydromorphological features document

Preliminary list of hydromorphological features to support data analysis and interpretation for WP2 activities

Prepared by C. Casalegno, J. Kail, A. Buffagni
CNR-IRSA, UDE

Principal hydromorphological features

Subject
List of hydromorphological features (natural and anthropogenic) which can be used to study the relation between land-use and hydromorphology in WP2, subtask 1.1 catchments.

General List

- Sinuosity/Planform
- Straight or curved reach
- Number of wetted channels
- Channel position (Left-Center-Right)
- Water widht
- Max water depth

- Bank features
- Bars (point bars, side bars concave bars, alternare bars, mid-channel bars, etc.)
- Feature indicating natural channel dynamics/ Extent of special features (e.g. large waterfalls, debris dams etc.)
- Riffle and steps
- Channel features
- Flow type & diversity
- Channel substrate type & diversity
- Cross-section depth (depth: width)
- Artificial features
- Artificial backwaters
- Channel artificial substrate/Bed fixation
- Cross section form/bank erosion-deposition and profile
- Woody riparian vegetation/extent of riparian tree cover/Bank vegetation structure (bank face and bank top)
- Land-use within 50m of channel/none woody riparian vegetation
- Bank modifications-retrevements
- Channel in-stream vegetation

Attributes

- **sinuosity/planform**:
  - normally, in fluvial morphology is used sinuosity, based on "channel length / valley axis length" ratio;
  - planform can be classified using the deviation of the stream axis from the valley axis (maximum angle between the stream axis and the valley axis)
    - heavily meandering (>60°)
    - meandering (30-60°)
    - highly curved (10-40°)
    - curved (<20°)
    - slightly curved (<20°)
    - straight (no deviation stream axis / valley axis)
    - straightened (no deviation stream axis / valley axis)

other simpler measures can be used based on map analysis.

- **number of wetted channels**
- **Channel position (Left-Center-Right)**
- **Water widht**
- **Max water depth**

Bank features

- **Natural Berms (NB)** are transitional features between depositional bars and terraces on the floodplain. The profile must have a marked step or a composite profile, with rodges representing a series of deposition/incision events (RHS Guidance Manual, page 3.17).
- **bank erosional features**:
  - Eroding Cliff. Bankface profile is predominantly vertical, with a minimum height of 0.5 m and showing a clean face.
  - Stable Cliff. Bankface profile is predominantly vertical, with a minimum height of 0.5 m and without obvious signs of recent erosion.
  - Eroding bank. Shows a profile evidencing erosional action of river on bank substrate; its profile is not necessary predominantly vertical and it has not a minimum height.
  - Toe. It is slumped material at bank base, originating from river eroding action on banks. It can be distinguished from side bars by its composition material: it is composed of the same material of the banks and not of the river bed material, as for side bars

Depositional features:

- **Bars** (see figures below) are distinctive depositional features which
  - are exposed at low flow, with a shallow slope into the water
  - are composed of unconsolidated river bed material and not of bank material.

  They can be distinguished in:

Bank Depositional features (according to bar classification of Church,1992, integrated)**:**

Point bars, located on the inside of a distinct meander bend in actively eroding/depositing rivers.

Concave bars, located on the outside of a distinct meander bend in actively eroding/depositing rivers.

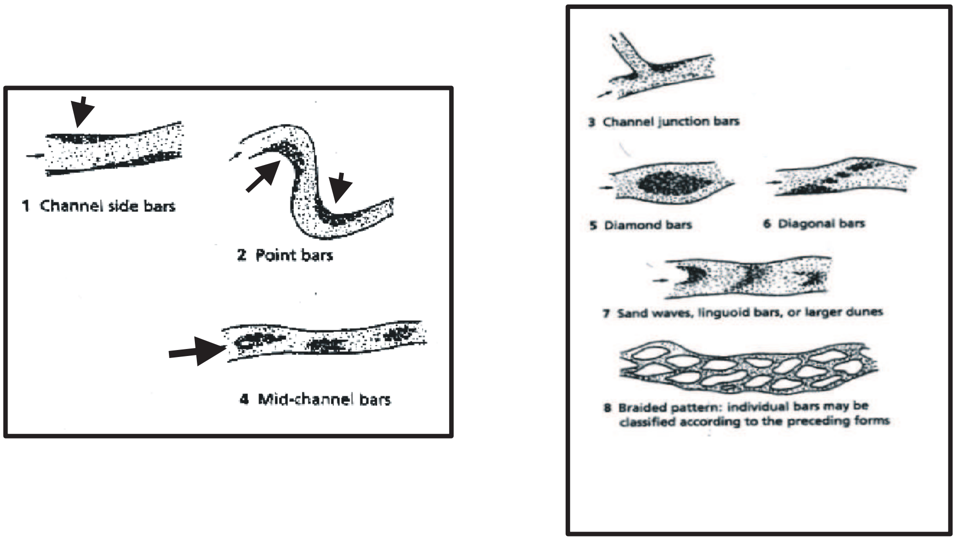
Side bars, located along the margins of rivers, in straight river reaches.

Alternate bars, side bars located at the opposite margins of rivers, facing among them in an alternate way.

Channel Depositional features:

Mid-channel bars, bar (composed of unconsolidated river bed material, exposed at low flow, with shallow sloping sides into the water) situated in-channel; its presence create multichannel river reaches. This definition can be used to indicate other two features: diagonal bars and multiple bars. They include **Diagonal bars and Transverse bars** (see figure below);

Multiple bars, (see figure below, under braided-pattern) are mid-channel bars not totally exposed from the water flow; a multiple bar may appear as many mid-channel bars separated by shallow water but it is a single mid-channel bar on which the water flows.



Sediment storage in bar structures
(Kellerhals & Church, 1989)

- **Features indicating natural channel dynamics/Extent of special features (e.g. large waterfalls, debris dams, side channels etc.)**
  - channel features, which indicate natural channel dynamics can be: large wood, wood accumulations, islands, multiple-channels, deposits, channel-widening, channel-narrowing

Sand deposits are either uderwater or exposed, in the channel or in the margins. The deposit must contrast with the predominant river bed substrates.

Sparse Deposit is a partially exposed river bed substrate area, which can be seen as beginning of a bar formation. Usually the water flows among sparse deposits material and vegetation can be present too.

Mature island Permanent in-channel feature with the surface at the same height, or above, the bankfull height. Usually well vegetated.

Comments: channel widening and narrowing often are difficult to see.

- **Riffles and steps**:
  - riffles of riffle-pool sequences and steps of step-pool sequences should be counted (for definitions of riffles and steps, see for example RHS field Guide, Knighton (1998), p. 193 ff and 201 ff)
- **Channel-bed features:**

  - channel bed features can be: scour pools, backwater pools, rapids, cascades (classification of channel featuresespecially based on Church (1992) and EA, 2003);
- F**low type/diversity**, **depth variability/maximun depth**, **substrate type/diversity**, **cross-section width variability**: For flow type and substrate definitions see RHS Field Guidance.
- C**ross-section depth (depth : width)**:
  - the depth to width ratio was used to describe cross-section depth; different depth classes can be defined, for example:
    - very deeply entrenched, >1:3
    - deeply entrenched 1:3 to 1:4
    - entrenched 1:4 to 1:6
    - shallow 1:6 to 1.10
    - very shallow <1:10
- **Artificial features**

  Bridges, Dams, weirs, sluices, fords, outfalls/intakes, culverts, deflectors/groynes/croys:
  - the presence, position and length of artificial features can be mapped; in addition it can be recorded, if natural sediment is present on the stream bed in the culvert or if erosion activity is present at base of bridges for example.
- **Artificial backwaters, ponding**:
  - artificial backwaters caused by dams or weirs can be mapped according to the reduction of flow velocity compared to free flowing sections.
- **Channel artificial substrate**/B**ed-fixation**:
  - the type (see below) and extent (10-50%, >50%) of bed-fixation can be mapped
    - riprap
    - cobbled pavement
    - concrete with sediment on top
    - concrete without sediment on top
    - see other RHS categories

- C**ross-section form/bank erosion-deposition and profile**:
  - different cross-section forms can be mapped according to the following categories:
    - natural cross-section
    - near-natural cross-section
    - unstable eroding cross-section
    - derelict trapezoidal or rectangular cross-section
    - deeply entrenched cross-section
    - trapezoidal cross-section
    - rectangular cross-section
  - different bank erosion-deposition features and profiles can be mapped:
    - Eroding/stable cliffs
    - Eroding bank
    - Foot
    - Point bars, Side bars, alternate bars, concave barsnatural cross-section
  - different bank profiles can be mapped
    - Natural: vertical, steep, Gentle, composite
    - Artificial: resectioned, Reinforced, Embanked, Poached, artificial two stage, set back embankments.
    - see other RHS categories

- **Woody riparian vegetation/ Extent of riparian tree cover/banktop and bankface vegetation structure**

  - different types of woody riparian vegetation can bee distinguished
    - native forest
    - gallery of native tree species
    - partly native forest or gallery of native tree species

        - native single trees / shrubs
        - none-native forest or gallery
        - none-native single trees / shrubs
    - different extent of riparian cover can bee distinguished
        - none
        - isolated/scattered
        - regularly spaced, single
        - Occasional clumps
        - Semi-comtinuous
        - Continuous

    - **Different banktop and bankface vegetation structure can be distinguished**
        - Bare
        - Simple
        - Uniform
        - Complex
        -
- **land use within 50 m/ none-woody riparian vegetation**:
    - different land use categories
        - Broadleaf/mixed woodland
        - Coniferous plantations
        - Etc
    - different types of none-woody riparian vegetation can be distinguished :
        - cane
        - perennial herbs
        - pasture
        - no none-woody vegetation naturally
        - no none-woody vegetation, because of bank-erosion
        - no none-woody vegetation, because of bank-revetment or embankment

- B**ank modifications-revetment**:
    - The type and extent of bank modifications can be mapped:
        - Resectioned
        - Rinforced
        - Poached (bare)
        - Artificial berm
        - Embanked
        - Trash
    - the type (see below) and extent (10-50%, >50%) of bank-revetment can be mapped:
        - gallery of trees
        - riprap
        - wooden bank-revetment
        - sod (Böschungsrasen)
        - cobbled pavement (Pflaster, Steinsatz, unverfugt)
        - unauthorized revetment like building rubble (wilder Verbau)
        - concrete (Beton, Mauerwerk, Pflaster)

- **Channel vegetation:**
    - The type and extent of channel vegetation can be recorded

Hydromorphological Survey Methods

- **RHS method (RHS)**; parameters mapped for 500 m stream sections, along 10 equally spaced transects. It is the NERC hydromorphological survey method adopted for analysis of relations between hydromorphology-land-use.

- **River Habitat Survey South European version (RHS SE);** it is the hydromorphological survey method adopted by CNR for collecting data for the analysis of relations between hydromorphology-land-use-biota.

General comments on the RHS and RHS SE survey method

The River Habitat Survey (RHS) method was chosen for application and adaptation to the Italian and South European situation because of its wide range of possible outcomes and for the objective approach in describing the riverine environment (Buffagni & Kemp, 2002).

RHS is a methodology developed by the Environment Agency of England and Wales (Raven *et al*. 1998a; 1998b; Environment Agency 1997), which is extensively applied in Britain and Northern Ireland. It is a technique for the assessments of river habitats, which aims to provide nation-wide conservation-relevant information about the physical state of rivers. RHS employs a method that records a large set of qualitative and quantitative data, which complements other data, such as water quality/chemistry data or biological survey (Raven *et al*. 1998a) and allows the direct comparison of sites, enabling, for example, an investigation of river types (Jeffers 1998) and the identification of high quality and impoverished sites (Raven *et al*. 1998a).

An important development is that, in addition to the collection of qualitative information for each site, bank and in-channel features are ‘sampled’ for 10 transects, spaced at 50 m intervals. This converts essentially qualitative data into weakly quantitative variables (Jeffers 1998) which allows quantitative testing, analysis and unbiased comparison between rivers.

The method has been further ameliorated during the last three years, and the final verson will be available for WP2 partners (if they are interested) by the end of February 2005.

- **LAWA-method,** (briefly described by Raven et al., 2002) 25 parameters mapped for stream sections 100 m in length; it is the UDE hydromorphological survey method adopted for analysis of relations between hydromorphology-land-use.

General comments on the LAWA method

- the mapping method was developed by regional authorities in the mid-1990’s to assess the hydromorphological state of the stream sections; slightly different methods have been applied in the surveys performed by the individual federal states, but they do essentially correspond to the field survey method of the “Länderarbeitsgemeinschaft Wasser” (LAWA) briefly described by Raven et al. (2002)
- the results of the LAWA hydromorphological survey method can be analysed and interpreted at different levels of resolution: the attributes listed in Table 1 are recorded and grouped into six “main categories”, further aggregated into three “higher categories” (stream bed, stream bank, floodplain) and finally into a single value
- all attributes are recorded along 100 m channel segments and compared to a reference condition, which is defined as the “potential natural state” of the stream (the condition that would result naturally without further human intrusion); the assessment results of the individual attributes are used to calculate a result for each of the six “main categories”; these results are finally gauged by the expert (surveyor) in relation to the presumed reference condition; possible results range from unchanged (only minor deviations from the reference condition, class 1) to heavily degraded (class 7)
- => the objective of the mapping was to assess the hydromorphological state, not to exactly map all channel-features (no “inventory”); terms / classification of the channel-features are only partly based on a sound scientific basis and the terms / classification for some channel-features do not correspond to the ones generally used in fluvial science (e.g., fluvial morphology)

- **Ökomorphologische Zustandtskartierung**; used by BOKU.

To be described

References

Buffagni A. & J. L. Kemp, 2002. Looking beyond the shores of the United Kingdom: addenda for the application of River Habitat Survey in Southern European rivers. *Journal of Limnology*, 61(2): 199-214.

Church, M. A., McLean, D. G., Wolcott, J. F., 1987. River bed gravels: Sampling and analysis. in: C. R. Thorne, J. C. Bathurst, R. D. Hey. Sediment transport in gravel-bed rivers. John Wiley & Sons, Chichester, 789.

Environment Agency, 1997. *River Habitat Survey, 1997 field survey guidance manual*. Environment Agency.

Environment Agency, 2003. River Habitet Survey in Britain and Ireland - Field Survey Guidance Manual: 2003 Version. Warrington, Cheshire WA4 1HG.

Jeffers, J.N.R., 1998. The statistical basis of sampling strategies for rivers: an example using River Habitat Survey. *Aquatic Conservation-Marine and Freshwater Ecosys-tems*, 8: 529-540.

Kellerhalls R & M. Church, 1989. The morphology of large rivers: characterization and management. In: Dodge DP (ed). Proceedings of the International Large Rivers Symposium. Canadian Special Publication of Fisheries and Aquatic SCIENCES. 106: 31-48.

Knighton, D., 1998. Fluvial forms and processes. Oxford University Press, New York, 383.

Raven, P.J., N.T.H. Holmes, F.H. Dawson & M. Everard, 1998a. Quality assessment using River Habitat Survey data. *Aquatic Conservation-Marine and Freshwater Eco-systems*, 8: 477-499.

Raven, P.J., N.T.H. Holmes, F.H. Dawson, P.J.A. Fox, M. Everard, I.R. Fozzard, & K.J. Rouen. 1998b. *River Habitat Quality: the character of freshwater streams and rivers in the UK and Isle of Man*. Rep. No. Report No. 2. Environment Agency.

Raven, P. J., Homes, N. T. H., Charrier, P., Dawson, F. H., Naura, M., Boon, P. J. 2002. Towards a harmonized approach for hydromorpological assessment of rivers in Europe: a qualitative comparison of three survey methods. Aquatic Conservation: Marine and Freshwater Ecosystems (12), 405-424.

ANNEX 3: Task 1.1 Partners details and e-mail addresses

Partner	Contact person	e-mail
CNR	Carlotta Casalegno	casalegno@irsa.rm.cnr.it
CNR	Andrea Buffagni	buffagni@irsa.rm.cnr.it
ALTERRA	Piet Verdonschot	Piet.verdonschot@wur.nl
BOKU	Thomas Ofenböck	thomas.ofenboeck@boku.ac.at
NERC	John Murphy	jomu@ceh.ac.uk
MasUniv	Karel Brabec	brabec@sci.muni.cz
SLU	Leonard Sandin	Leonard.sandin@ma.slu.se
UDE	Jochem Kail	jochem.kail@uni-essen.de
UNIBUC-ECO	Carmen Postolache	carmen@bio.bio.unibuc.ro