RiverCare

Knowledge Dissemination Days

October 31 – November 1, 2016

Towards self-sustaining multifunctional rivers

Enabling new technology

NCR PUBLICATION 40-2016
ISSN 1568-234X

Knowledge Dissemination Days

October 31 – November 1, 2016

Rijkswaterstaat, Utrecht, The Netherlands

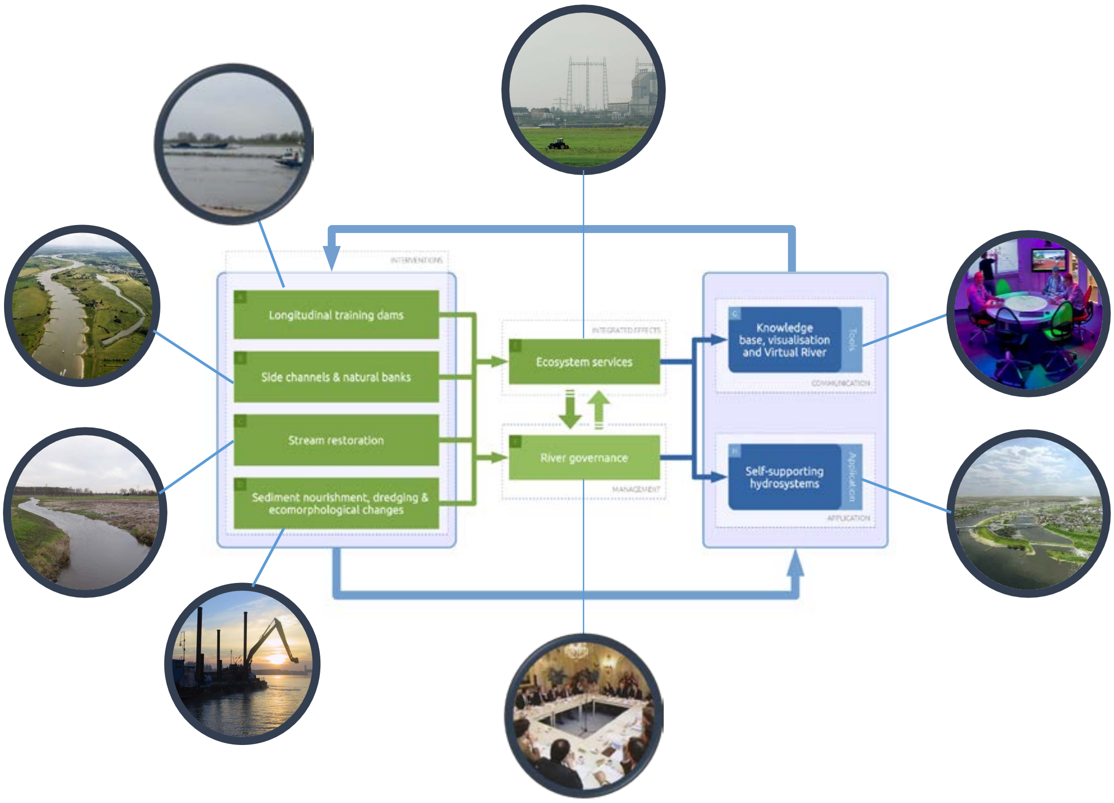
Photo cover: Waal near Nijmegen, Johan Roerink, Aeropicture.nl (Beeldbank Rijkswaterstaat)

Towards self-sustaining multifunctional rivers

RiverCare is a research programme funded within the so called Perspectief Programme of the Dutch Science and Technology Foundation (STW), and consists of 20 research positions at 5 different Dutch universities in cooperation with many public and private partners (see below). RiverCare will run from 2014 to 2019.

Objective

To get a better understanding of the fundamental processes that drive ecomorphological changes in rivers, predict the intermediate and long-term developments and develop best practices to reduce the maintenance costs and increase the benefits of interventions. RiverCare is a combination of **fundamental research**, river engineering **applications** and state of the art **visualisation** tools.



RiverCare is also about cooperation. In a joint effort, universities, knowledge institutes, consultancy firms and the government acted together and defined the challenges that need to be solved for optimal river management.

Poster presented at EGU 2014 and NCR-days 2015

Preface

This document contains a brief summary (the so-called two-pagers) of all the subprojects in RiverCare and serves as background information for the knowledge dissemination days on October 31 and November 1, 2016 and the mid-term review on November 2, 2016.

RiverCare is a 5.7 million-euro research programme, in which universities, government, knowledge-institutes and high-end consultancy firms work together on the challenges in river research and river management. RiverCare was granted in 2013 by the Technology Foundation (STW) of the Netherlands Organization for Scientific Research (NWO), started effectively in 2014 and will end in December 2019. There are 16 PhD-students, 3 postdocs and 2 junior researchers working in RiverCare at 5 different universities in The Netherlands.

More information on RiverCare can be found on: http://www.ncr-web.org/rivercare/about

Suzanne Hulscher
Ralph Schielen
Denie Augustijn

Definitief programma

De meeste sessie worden twee keer gehouden zodat flexibel gekozen kan worden.

Dag 1- Maandag 31 Oktober 2016

Tijd	Sessie (Zaal)	
9:00 9:30	Opening (E1.16)	
9:30 11:00	S1.1 (E1.16)	S2.1 (E1.46)
11:15 12:45	S1.2 (E1.16)	S2.2 (E1.46)
12:45 13:30	Lunch	
13:30 15:00	S1.1 (E1.16)	S2.2 (E1.46)
15:15 16:45	S1.2 (E1.16)	S2.1 (E1.46)
16:45 17:00	Sluiting (E1.16)	
17:00	Borrel	

Sessie 1.1 Langsdammen, nevengeulen en oevers

- **Timo de Ruijscher** *Hydro- en morfodynamica van langsdammen*
- **Pepijn van Denderen:** *Morfologische veranderingen in nevengeulen*
- **Gonzalo Duro:** *Natural erosion processes**

Sessie 1.2 Sediment management maatregelen

- **Liselot Arkesteijn:** *Historie en lange termijn voorspellingen*
- **Victor Chavarrias:** *Mathematical modelling**

Sessie 2.1 Ecologische monitoring

- **Frank Collas:** *Ecologie van langsdammen*
- **Wimala van Iersel:** *Monitoring van uiterwaardvegetatie*

Sessie 2.2 Uiterwaarden

- **Valesca Harezlak:** *Ontwikkeling van vegetatie in uiterwaarden*
- **Remon Koopman:** *Ecosysteemdiensten van riviersystemen*

Dag 2- Dinsdag 1 November 2016

Sessie 3.1 Beleving en samenwerking in het rivierengebied

- **Jan Fliervoet, Wessel Ganzevoort, Riyan van den Born**

Sessie 3.2 Ondernemen met ecosysteemdiensten - verantwoordelijkheden en dilemma's

Astrid Bout, Swinda Pfau

Sessie 4.1 Keuze van maatregelen om de juiste reden

- **Menno Straatsma:** *Rivierbeheer: optimalisatie maatregelen en mogelijkheden*
- **Robert-Jan den Haan:** *Scenarioverkenning met gaming tool*
- **Koen Berends:** *De toekomst van modelbeheer*

Sessie 4.2 Gezamenlijk kennis platform en exportmogelijkheden*

- **Juliette Cortes, Nick Leung**

Sessie 5 Regionale Systemen

- **Jasper Candel:** *Het morfodynamisch functioneren van laaglandbeken*
- **Tjitske Geertsema:** *Samenvallen van afvoergolven met hoofdrivieren*

Tijd	Sessie (Zaal)	
9:00 9:30	Opening (E1.16)	
9:30 11:00	S3.1 (D1.25)	S5 (D1.29)
11:15 12:45	S3.2 (D1.37)	
12:45 13:30	Lunch	
13:30 15:00	S4.1 (H2.42)	S5 (D1.37)
15:15 16:45	S4.2 (H2.42)	
16:45 17:00	Sluiting (E1.16)	
17:00	Borrel	

** Presentatie in het Engels*

Locatie: Rijkswaterstaat, Griffioenlaan 2 Utrecht, The Netherlands

Table of Content

A1: Hydraulics and morphology of longitudinal training dams

Project:	**A: Optimizing longitudinal training dam (LTD) design**
Researcher:	Timo de Ruijsscher
Project leader:	Dr ir Ton Hoitink
Supervisors:	Dr ir Ton Hoitink, dr ir Bart Vermeulen, prof dr ir Wim Uijttewaal, dr ir Erik Mosselman, prof dr ir Remco Uijlenhoet (Promotor)
Started:	03 2015
Contract until:	03 2019

timo.deruijsscher@wur.nl

Research description

In the Dutch river system, measures are taken to keep the river system sustainable for the future. One way of doing this, is by replacing transverse groynes in the inner river bend by so-called longitudinal training dams (LTDs, see Figures 1–2). As a pilot project, LTDs are constructed over a ten-kilometre stretch in the Waal River. LTDs are expected to reduce long-term subsidence, increase the lowest water levels, increase the discharge capacity during floods and create ecologically more favourable conditions. However, existing knowledge about the effects of LTDs on erosion/deposition and regional flow patterns is highly limited.

The main aims of this research are to understand (a) the effect of the intake geometry of an LTD on the morphological patterns and associated flow structures in the inflow region, (b) the morphodynamic evolution of the bed in both the main channel and the side channel after construction of an LTD, (c) the dynamic behaviour of subaqueous dunes in the Waal River, and the influence of the LTD construction thereon and (d) the physical mechanisms governing exchange processes in LTD gaps. To achieve these goals, both physical scale model experiments and field measurements will be used.

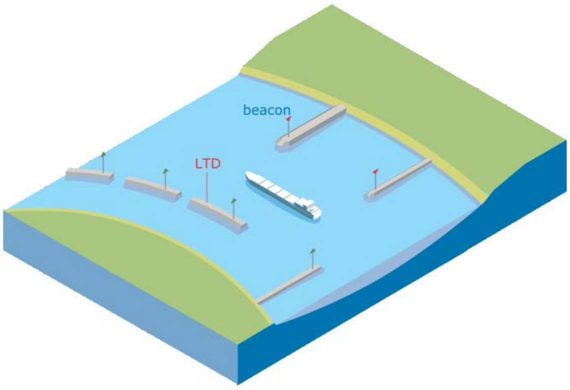


Figure 1. Schematic view of an LTD and the remaining groynes, adapted from (Rijkswaterstaat 2012).

Figure 2. The LTD in the Waal River near Ophemert, looking upstream. Picture from Rijkswaterstaat Oost-Nederland.

Results

In order to prepare the physical scale model experiments in the Kraijenhoff van de Leur Laboratory for Water and Sediment Dynamics at Wageningen University, a 1:60 physical scale model is built (see Figure 3). Scaling analysis is based on previous work by Vermeulen et al. (2014), including the use of polystyrene lightweight granules, as substitute sediment. To study the bed forms and their evolution during experiments, a new measurement approach has been developed (De Ruijsscher et al., in prep). A so-called laser line scanner consists of a laser projecting a line on the bed (see Figure 4). The reflected signal is picked up by a 3D-camera and the bed profile is reconstructed. Problems that occur using this method are data scatter and missing data. Both are reasonably resolved by using a fitting algorithm called LOESS (Cleveland & Devlin 1988), which also appears to be a useful tool for filtering bed forms of different spatial scales.

Figure 3. Scale model of the upstream section of a longitudinal training dam (1:60) in a 2.5-metre-wide flume in the Kraijenhoff van de Leur Laboratory for Water and Sediment Dynamics in Wageningen.

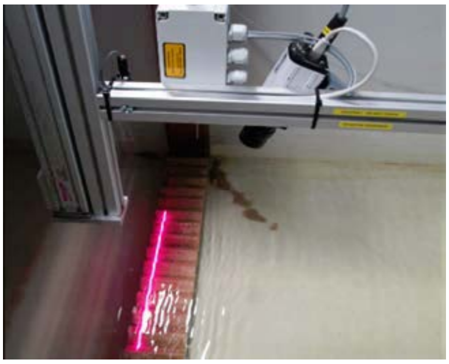


Figure 4. Laser line scanner set-up. A red laser line is projected on the bottom of the flume, which reflection is recorded by a 3D camera (top right).

Next steps

As the preparations in the lab are nearly completed, the scale model experiments will start in September. Field surveys including ADCP measurements will be carried out at the LTD near Ophemert starting autumn 2016. Two horizontal ADCPs and optical backscatter (OBS) devices will be mounted at a traffic pole at the upstream side of the Ophemert LTD. Finally, end of 2016 the first data gathered by Rijkswaterstaat will be accessible, which allows analysis of the morphological data.

References

Cleveland, W.S. & Devlin, S.J., 1988. Weighted regression: an approach to regresion analysis by local fitting. Journal of the American Statistical Association, 83(403), pp.596–610.

Rijkswaterstaat, 2012. Infographic: Kribverlaging en langsdammen van de Waal. Available at: https://www.ruimtevoorderivier.nl/project/kribverlaging-en-langsdammen-waal.

De Ruijsscher, T.V., Dinnissen, S., Vermeulen, B., Hazenberg, P., Hoitink, A.J.F. (in prep). Application of a line laser scanner for bed form tracking in a laboratory flume. Water Resources Research.

Vermeulen, B. et al., 2014. River scale model of a training dam using lightweight granulates. Journal of Hydro-environment Research, 8(2), pp.88–94

A2: Ecology of longitudinal training dams

Project:	**A: Optimizing longitudinal training dam (LTD) design**
Researcher:	Frank Collas
Project leader:	Dr ir Ton Hoitink
Supervisors:	Dr Rob Leuven, dr ir Tom Buijse, prof dr ir Jan Hendriks (promotor)
Started:	09 2014
Contract until:	09 2018

Radboud University

f.collas@science.ru.nl

Research description

Freshwater ecosystems are among the most endangered ecosystems in the world. Especially lowland rivers have been substantially modified to increase flood safety and to allow navigation thereby reducing habitat and increasing flow variability, pollution, overexploitation of water and navigation-generated disturbance. Lowland river banks are often characterized by a high disturbance regime due to navigation-generated waves, increased water flow, bank erosion and agitation of the sediment layer, resulting in low biodiversity and dominance of invasive exotic species. In order to mitigate navigation induced high disturbance regimes and to improve discharge capacity, longitudinal training dams (LTDs) were built in the river Waal in the Netherlands. LTDs are river training structures aligned parallel to the river shore, thereby protecting the river banks from navigation-induced impacts, possibly allowing the development of sheltered lotic habitats and gentle slopes that at the same time experience less hydro-morphological disturbance. Knowledge on the relation between multiple physical stressors and habitat requirements of riverine species is required to evaluate and optimize the design of LTDs. Therefore, this study aims to develop ecological knowledge that can be used to optimize the design and management of LTDs and other river training structures from an ecological perspective. Field and laboratory based species sensitivity distributions (SSDs) will be derived to analyze the variation among species in their sensitivity to (multiple) environmental factors. These SSDs can be used 1) to predict the effect of changing abiotic conditions on riverine species pools, and 2) to rank abiotic factors based on their impact on riverine biodiversity. Field monitoring of biota and abiotic conditions near the LTD and traditional river training structures will be performed, thereby providing an opportunity to validate the SSDs.

Results

SSDs were constructed for European riverine species for several environmental factors (i.e., flow velocity, temperature, air exposure/desiccation, dissolved oxygen, water depth, dislodgement force, shear stress; Collas et al. 2014; Collas et al., in prep) and several species groups (fish, crustaceans, molluscs, insects and aquatic plants) (Figure 1). Moreover, a method was developed to interpolate point measurements of abiotic conditions into spatial maps. These maps were subsequently used to calculate the potentially not occurring fraction (PNOF) of species in relation to environmental conditions factor level using constructed SSDs (Collas et al. 2015). The derived PNOF maps enable calculations of suitable habitat areas and volumes for various species groups. This approach allows to assess and to predict effects of LTD designs and other river training structures on biodiversity.

Abiotic conditions behind the LTD were measured with a focus on navigation induced effects (i.e., flow velocity, water level variation, water dynamics, water temperature and suspended sediment) in comparison with traditional groyne fields and side channels. Additionally, the speed, navigation direction, type of navigation and distance to passing navigation were measured. Navigation induced effects were greatly reduced and less variable behind the LTD compared to traditional groyne fields. Thus, the LTD protects the river banks from navigation-induced impacts thereby allowing the development of sheltered lotic habitats. Juvenile fish densities were indeed found to be higher near the LTD compared to the traditional groyne field.

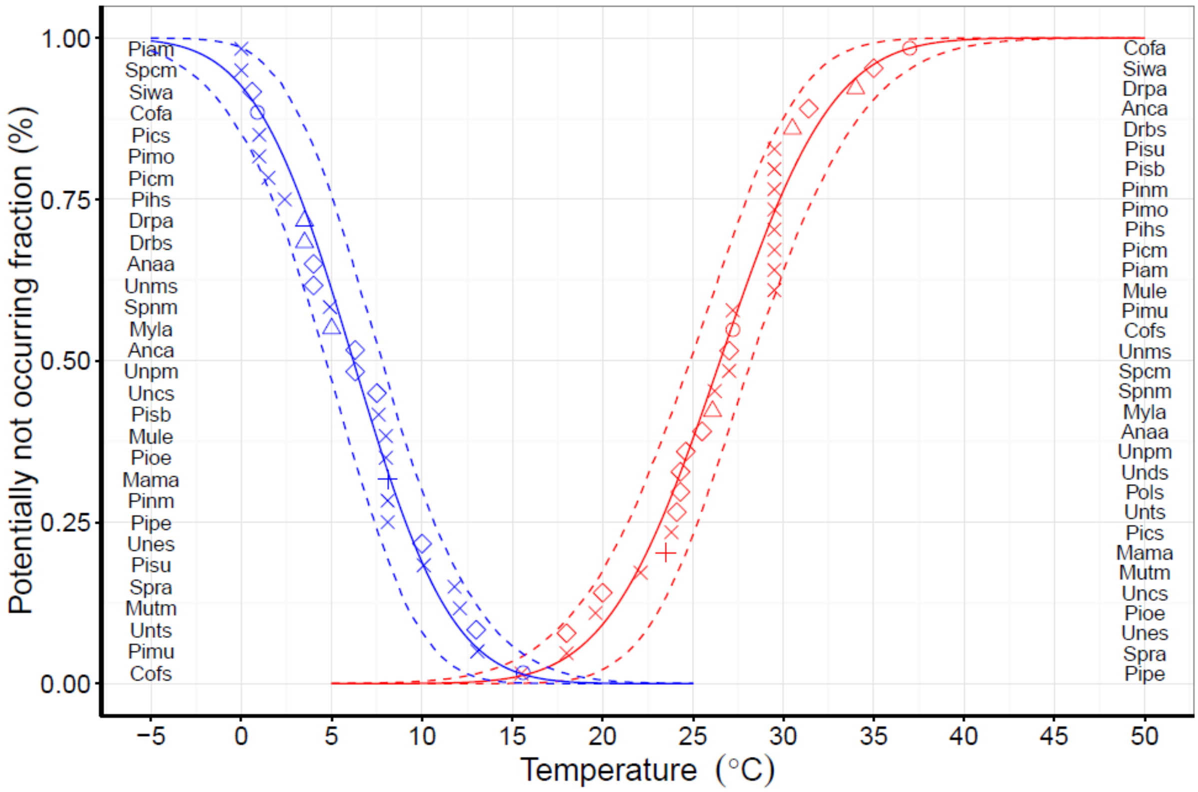


Figure 1. Sensitivity distribution for the minimum habitat temperature (blue line) and maximum habitat temperature (red line) of European freshwater bivalve species, including their 2.5 and 97.5% confidence intervals (dotted lines). The different symbols represent species of the families Corbiculidae (circles), Dreissenidae (triangles), Sphaeriidae (crosses), Unionidae (diamonds) and Margaritiferidae (plus signs). For each data point the according species abbreviation is listed.

Next steps

Additional data concerning the abiotic conditions near LTDs will be acquired as well as additional data on presence and abundance of biota. These spatiotemporal abiotic data will be combined with the constructed SSDs in order to assess positive and/or negative effects of LTDs on biodiversity. The results will be used to recommend opportunities for fine tuning design and management of LTDs in order to optimize their ecological potential. Moreover, the SSDs will be linked to HABITAT, a freely available online tool of Deltares that allows to calculate habitat suitability and to apply this ecological knowledge in other international cases in river science and management.

References

Collas, F.P.L., Koopman, K.R., Hendriks, A.J., Van der Velde, G., Verbrugge, L.N.H. & Leuven, R.S.E.W. (2014) Effects of desiccation on native and non-native molluscs in rivers, Freshwater biology 59, p41-55.

Collas, F.P.L., Buijse, A.D., Hendriks, A.J. & Leuven, R.S.E.W. (2015) The use of species sensitivity distributions and monitoring to predict the ecological effect of longitudinal training dams. In: Lenders, H.J.R., Collas, F.P.L., Geerling, G.W., & Leuven, R.S.E.W. (Eds). (2015). Bridging gaps between river science, governance and management. NCR days 2015, NCR-publication 39-2015, p101-104.

Collas, F.P.L., Buijse, A.D., Hendriks, A.J., Van der Velde, G. & Leuven, R.S.E.W. Sensitivity of European freshwater bivalve species to climate related environmental factors, (in prep.)

B1: On the dynamics of side channels as restoration measure: linking theory and practice

Project:	**B: Side channels and erosion of natural banks**
Researcher:	Pepijn van Denderen
Project leader:	Prof dr ir Wim Uijttewaal
Supervisors:	Dr Ralph Schielen, prof dr Suzanne Hulscher (promotor)
Started:	12 2014
Contract until:	12 2018

UNIVERSITY OF TWENTE.

r.p.vandenderen@utwente.nl

Research description

Side channels are a common feature of natural rivers, but they disappeared due to river regulation. In several European and North-American rivers, river restoration project have been initiated to reconstruct side channel systems with the intention to reduce the flood level, to increase the ecological value of the river and to reduce the degradation of the main channel. These side channels aggrade or degrade due to construction properties, which means that regular maintenance is required. However, this maintenance is expensive and undesirable, and should therefore be avoided as much as possible. A better understanding of the mechanisms which lead to morphological changes in side channel systems, most likely will optimize the design and therefore the maintenance cost, resulting in a more sustainable river.

The mechanisms which influence the morphological development are identified by studying several existing side channels. With a simple 1D numerical model, we are able to reproduce some of these mechanisms, but others require 2D/3D modeling. The goal is to identify the essential mechanisms, predict the behavior and define rules of thumb which can be used to design a stable side channel.

Results

Studying aerial images of several side channel systems, the following mechanisms are found to affect the erosion/sedimentation patterns: a difference in slope between the main and side channel, bend flow at the bifurcation, the bifurcation angle, presence of suspended sediment transport or mixed sediment and presence of vegetation and bank erosion. Figure 1 shows an example of a two channel system in the River Ain, France, near the village of Mollon. Just after 1968 the west channel closed, but due to a flood in 1996, the channel is reopened. Between 1968 and 1996 the meandering of the river lengthened the east channel and therefore created a difference in length between the east and west channel. Due to the difference in length, the west channel attracts more discharge after reopening causing erosion in the channel, while the discharge in the east channel reduces leading to sedimentation. From 2003, the main discharge is conveyed by the west channel and as a result, between 2005 and 2010 the east channel is closed. The vegetation, which is visible in the channel in 2010, most probably increased the sedimentation and accelerate the closure of the channel.

With a simple 1D numerical model (Kleinhans et al., 2011), we are able to reproduce the effects of a slope difference and reproduce the morphological changes like those that occurred in the River Ain. With this model and when the bend radius and length ratio of the channels is known, we can give a first estimate under which conditions a side channel becomes the dominant channel (red area, Figure 2). In addition, a time scale can be retrieved which gives a first indication of the morphological changes.

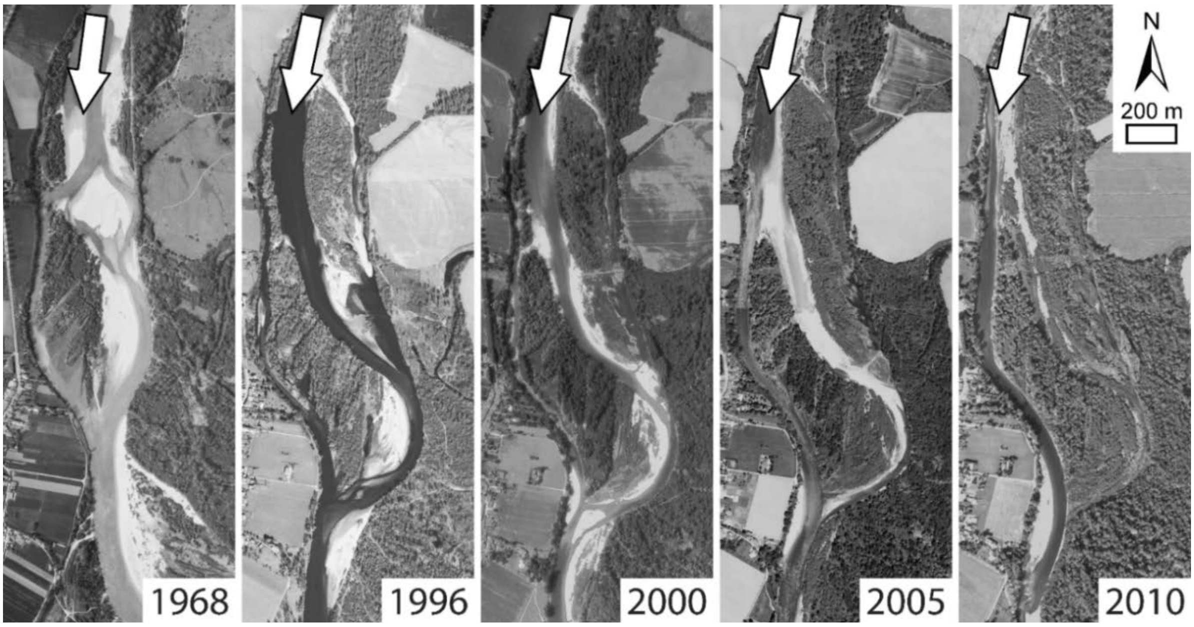


Figure 1. The morphological changes in a two channel system in the River Ain (France) near the village Mollon. (IGN-France, Google Earth)

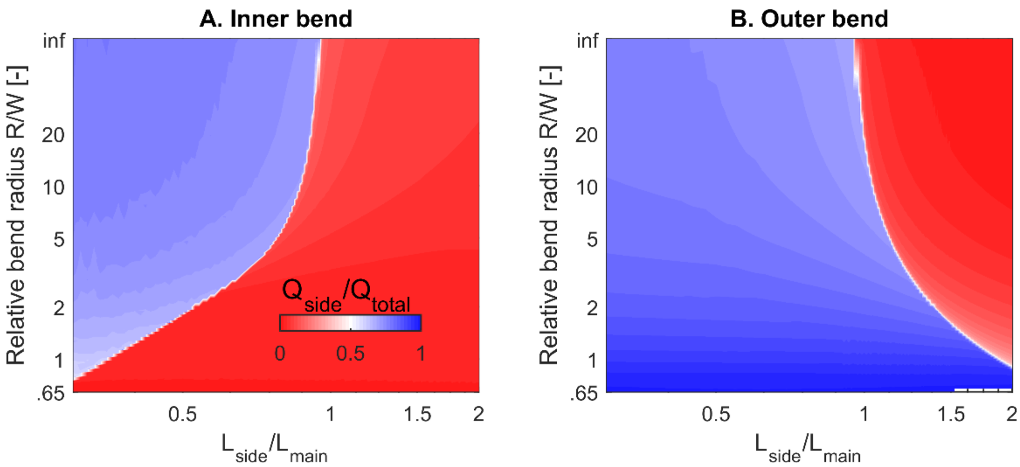


Figure 2. The results of the 1D numerical model for various side channel lengths and bend radii upstream of the bifurcation. (A) The side channel is located in the inner bend, (B) The side channel is located in the outer bend.

Next steps

The 1D numerical model gives a first estimate of the slope difference between the channels, bend flow and bank erosion. However, the other identified mechanisms are insufficiently represented in the 1D model and therefore 2D/3D computations are required. These computations focus on three mechanisms: the formation of a plugbar due to a large bifurcation angle, suspended sediment at the bifurcation and the effect of a sill at the entrance of the side channel which regulates the discharge and blocks part of the sediment transport.

References

Kleinhans, M. G., K. M. Cohen, J. Hoekstra, and J.M. IJmker (2011). *Evolution of a bifurcation in a meandering river with adjustable channel widths, Rhine delta apex, The Netherlands*, Earth Surface Processes and Landforms 36, p2011-2027. doi:10.1002/esp.2222.

B2: Natural bank erosion processes

Project:	**B: Side channels and erosion of natural banks**
Researcher:	Gonzalo Duró
Project leader:	Prof dr ir Wim Uijttewaal
Supervisors:	Prof dr ir Wim Uijttewaal (promotor) dr Alessandra Crosato, Prof dr Maarten Kleinhans
Started:	04 2015
Contract until:	04 2019

TU Delft

g.duro@tudelft.nl

Research description

Bank erosion in rivers is a natural process that constitutes one of the key elements of river morphodynamics. As found in natural conditions, it allows for the rejuvenation and presence of diverse habitats for aquatic plants and animals, which enhances the river ecological functions. However, the reduction or absence of bank erosion is often sought in favour of diverse human needs, such as navigation and flood protection, or simply to avoid property damage and land loss. Typical bank stabilization techniques in the Dutch context are groynes and rip-rap. There is a fairly good qualitative understanding of the bank erosion process, yet the prediction of erosion magnitudes and rates is a challenge and seldom accurate. This research aims at deepening the understanding of bank erosion as occurs in unprotected settings, in the search for ways of enhancing the conditions for more natural habitats when limited erosion is acceptable. Also, since vegetation is known to contribute to bank strength, this project will investigate the possibility and values of using vegetation for bank stabilization. Overall, the research added value will be a deeper understanding of bank erosion processes from an academic point of view, whereas from a practical perspective it aims at a strategy for balancing riverbank ecological functions with stabilization techniques and an improved modelling approach for bank erosion prediction.

Figure 1. Naturally eroding bank in the Maas River.

Results

The methodology includes case studies with all variables and complexities. Field visits and analysis of a study reach in the Maas River near Boxmeer has been the focus of attention for interpreting erosion drivers, among which vessels, floods and groundwater have been identified as potential major ones. The figure below is a top view of the site, which shows that within this reach the erosion patterns differ from uniform to embayments. Possible explanations include the presence of trees, different soil compositions and groundwater drainage. The figure also presents the river bathymetry after five years of removing the bank protection. Two terraces at the banks indicate the role of vessels in inducing submerged erosion and wave erosion at the water surface level. Yet, floods could also contribute to bank erosion generating a positive feedback between these drivers. The banks are stratified with varying transversal height, which may induce different erosion mechanisms as the bankline retreats. The presence of vegetation makes an impact on the erosion rates that varies, among other things, according to the relative size of the root system, its distribution and density.

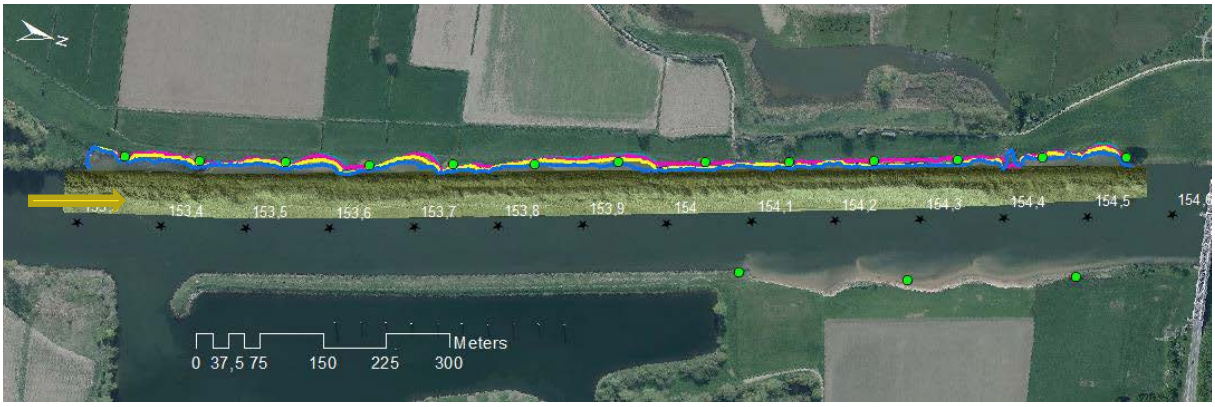


Figure 2. Bank lines in the Maas over four years of naturally eroding conditions (blue 2011, yellow 2012, pink 2013, green 2014).

Next steps

With the goal of identifying the drivers of erosion, their mechanisms and the relative contribution of each to predict the rates of bank erosion in this case study, further steps include the definition and execution of a field campaign in the Maas reach to quantify the hydraulic loads, from both ships and floods, together with the assessment of the performance of bank erosion models. The characterization of soils and direct erosion rates due to shear stress is also within the necessary steps. The analysis of the past records of erosion rates, bathymetries and vegetation distribution will be done to better understand the riverbank dynamics.

References

ASCE Task Committee on Hydraulics, Bank Mechanics and Modelling of River Width Adjustments (1998a). River width adjustment II. Processes and mechanisms. Journal of Hydraulic Engineering, ASCE, 124(9): 881-902.

Rinaldi, M., & Darby, S. E. (2007). 9 Modelling river-bank-erosion processes and mass failure mechanisms: progress towards fully coupled simulations. Developments in Earth Surface Processes, 11, 213-239.

Samadi, A., E. Amiri-Tokaldany, and S. E. Darby. "Identifying the effects of parameter uncertainty on the reliability of riverbank stability modelling." Geomorphology 106.3 (2009): 219-230.

C1: Morphodynamic functioning of regional river systems

Project: **C: Regional River Systems**
Researcher: Jasper Candel
Project leader: Prof dr Jakob Wallinga
Supervisors: Dr Bart Makaske, Prof dr Jakob Wallinga (promotor)

Started: 12 2014
Contract until: 11 2019

jasper.candel@wur.nl

Research description

Predicting the morphological stream functioning is a key aspect in stream restoration projects, in order to prevent flooding or unwanted bank erosion, and to plan and minimize management. Currently, a knowledge gap exists between stream restoration demands and current understanding on the morphodynamic functioning of low-energy streams. In many stream restoration projects in lowlands, single-thread, sinuous streams are often seen as “natural” and used as a reference. However, it is often unknown when and how the sinuous planform formed and whether streams laterally migrated in the past. Since morphodynamic processes in lowland streams are slow, these processes should be studied on a longer time scale in order to make predictions for future morphological stream behaviour. Knowledge on the processes that affected the stream planform in the past will help water managers in restoring these processes in future stream restoration to create more self-sufficient streams.

Figure 1. Using ground-penetrating radar (GPR) to study the fluvial deposits in the Dommel valley.

Results

Low-energy streams in peatlands often have a high sinuosity. However, it is unknown how this sinuous planform forms, since lateral migration of the channel is hindered by relatively erosion-resistant banks. We created a conceptual model of Holocene morphodynamic evolution of a stream in a peat-filled valley, building on a palaeogeographic reconstruction using coring and ground-penetrating radar (GPR), and ^{14}C and OSL dating. The conceptual model shows that the stream planform is partly inherited from the Late-Glacial topography, reflecting stream morphology prior to peat growth in the valley. Moreover, the model shows that aggrading streams in a peat-filled valley often combine vertical aggradation with lateral displacement caused by attraction to the sandy palaeo-valley sides, which are more erodible than the valley-fill. Due to this oblique aggradation process, the stream literally becomes stretched out as channel reaches may alternately aggrade along opposed valley sides, resulting in increased sinuosity over time. Our conceptual model explains how sinuous planforms can form in peat-filled valleys without the traditional process of lateral migration. Improved understanding of the evolution of streams provides inspiration for stream restoration projects, and supports water managers in setting clear stream restoration goals.

Figure 2. Schematic sketch of the sinuous planform formation. The figure on the left and right are cross-sections of the valley-fill, explaining the rectangular stream planform by the process of oblique aggradation.

Next steps

Similar as for peat-land streams, it is unknown how lowland streams morphodynamically functioned in a coversand setting during the Holocene. Unknown is whether these streams actively migrate under natural circumstances, and whether the morphodynamic activity has changed over time due to processes such as land use- or climate changes. A palaeogeographic investigation on low-energy streams in a coversand dominated area will provide insight into the morphodynamic functioning of these streams both in their natural and human-influenced states. In collaboration with water managers the gained knowledge will be applied in stream restoration projects.

C2: Hydrological functioning of regional river systems

Project:	**C: Regional River Systems**
Researcher:	Tjitske Geertsema
Project leader:	Prof dr Jakob Wallinga
Supervisors:	Dr ir Ton Hoitink, dr ir Ryan Teuling, prof dr Jakob Wallinga (promotor)
Started:	9 2014
Contract until:	9 2018

WAGENINGEN UR

tjitske.geertsema@wur.nl

Research description

The current water policy aims at accelerating discharge to mitigate floods, but is causing problems, such as eutrophication, reduced (aquatic) biodiversity, drastic decline in groundwater levels, increased water levels during floods and prolonged drought, predominantly in urban and densely populated lowland areas. To address and prevent these problems in the Netherlands, the water policy should concentrate more on water retention according to the Dutch commission WB21 (Water Policy in the 21st century). Few of the existing strategies towards water retention have been evaluated regarding their functionality and quantified impacts on the regional water system. In this context, this research focusses on local and regional effects of water retention within stream restoration practice. The current practice of stream restoration involves the construction of meander bends and insertion of woody debris, asserting local controls on stream conveyance capacity. Backwater effects resulting from sharp bends and the obstruction by woody debris remain poorly understood to date, and are considered key sources of uncertainty in predicting the effects of stream restoration. Regionally, streams are typically analysed in isolation from the river system in which they debouch, with the risk of simultaneous occurrence of discharge peaks in the river and its tributaries. Within a sub-catchment, ground water variation near restored streams is rarely being analysed as a response to surface water dynamics. Progress in understanding stream restoration impacts on discharge dynamics requires more knowledge about the potential simultaneous occurrence of discharge waves in a river and its tributaries, and a deeper understanding of response time of surface-subsurface *water exchange.*

Results

<u>Probability of simultaneous occurrence of discharge peaks in the Meuse River and its tributaries, Dommel and Aa River</u>

The nine highest discharge peaks in the River Meuse coincide with discharge peaks of the tributaries Dommel and Aa in the period from 1999 to 2015. The simultaneous occurrence is mainly due to the average duration of the discharge peak of 9 days in the Meuse. The average time shift of the discharge peak at the confluence of about 3 days for the tributaries Dommel and Aa with the Meuse River is not enough to prevent simultaneous occurrence (Fig. 1). The precipitation patterns in the catchment areas are correlated due to the orographic influence in the study area. The correlation of the precipitation pattern is a necessity for the simultaneous occurrence at the confluence. The simultaneous occurrence is amplified as precipitation events occur at an interval of two to three days over the Western side of the Ardennes and the Dommel River basin. When discharge peaks coincide, the water level gradient in the River Meuse increases and the water level gradient in the tributaries Dommel and Aa decreases. The decrease of water level gradient indicates backwater effects in the tributaries due to simultaneous occurrence. The backwater height can increase to 1 a 1.5 meter in the Dommel and Aa River.

These findings have influence on the water management in the delta. The common practice to determine the discharge from stage-discharge relations is not applicable for confluence as the stage-discharge relationships show hysteresis-effects (Fig. 2). The backwater curves during the highest discharge peaks show the largest deviation with the normal stage-discharge relation. In addition, the exceedance level of the upstream stations of the confluence cannot be used for the downstream stations of the confluence due to an increase in water level and discharge at the confluence. The current water policy, which is focused on exceedance levels and stage-discharge relations, therefore, is not valid around confluences. Next to these international common practices, is the aim of the current Dutch water policy to retain water, so the large rivers will not discharge the water from the tributaries during flood situations. Water retention can have significant impact in this case study, because the water retention of at least seven days is required to experience less simultaneous occurrence. Water retention of seven days however provides an additional risk of a new precipitation event within the seven days, which should be retained too. Precipitation event intervals of seven days are very common in the temperate climate of the Meuse River Basin. In short, the water retention in the lowland temperate climate should be able to retain multiple precipitation events at once. The best strategy is to combine speeding of the discharge of the Dommel and Aa and retaining the rest of the discharge peak, up to seven days.

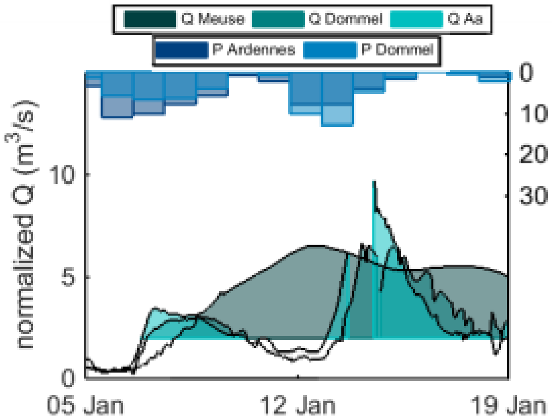


Figure 1. An example of simultaneous occurrence in 2011 for the Meuse River and Dommel and Aa tributaries.

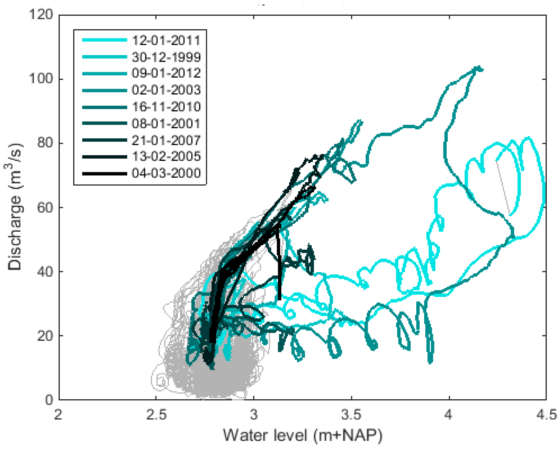


Figure 2. The stage-discharge relation of the Dommel River at the outlet.

<u>Quantifying backwater development due to woody debris</u>

Hourly water level and discharge time series are collected to analyze the water level effects of woody debris for five streams in the Netherlands. The water levels upstream of the woody debris show an increase of tens of centimeters after the insertion of woody debris. This increase exceeds the accuracy of the measurement instruments of approximately one centimeter. The water level gradient over the woody debris relates to discharge in the streams. This relation is characterized by an increasing water level gradient for a increasing discharge to a maximum for a certain discharge. If the discharge increases further than this maximum, the water level gradient reduces to approximately the water level gradient for the same discharge without the woody debris (Fig. 3). The researchers consider the blocking area of the woody debris as the main parameter to indicate the relation of water level gradient and discharge. However, the study is still in progress and aims to indicate the main parameters in the relation between the water level gradient and the discharge.

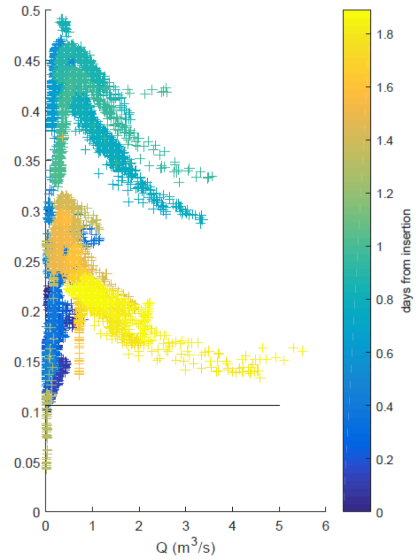


Figure 3. Relation between water level difference and discharge at Leerinkbeek.

D1: Improving the modelling of mixed sediment river morphodynamics

Project:	**D: Sediment nourishment and floodplain monitoring**
Researcher:	Victor Chavarrias
Project leader:	Dr ir Astrid Blom
Supervisors:	Dr ir Astrid Blom, dr Ralph Schielen, Prof dr ir Wim Uijttewaal (promotor)
Started:	09 2014
Contract until:	09 2018

TU Delft

v.chavarrias@tudelft.nl

Research description

Rijkswaterstaat has started a large scale nourishment field experiment in the German-Dutch border area, a part of the Rhine River specially relevant for its mixed-sediment properties (Figure 1). The mixed character of the sediment is a property necessary to explain physical phenomena as downstream fining of rivers (Sternberg, 1875), the gravel sand transition zone (Yatsu, 1955), the formation of bedload sheets (Seminara et al., 1996), the evolution of bars (Lanzoni and Tubino, 1999), or bed surface armoring (Parker and Klingeman, 1982).

In order to predict the evolution of rivers with multiple grain sizes we use mathematical models in which we impose the conservation of water mass and momentum and the mass of sediment of different size fractions. The conservation of sediment mass of different grain sizes poses a challenge: on the one hand the model needs to be *simple* as modelling the behavior of every single particle is de facto impossible; on the other hand it needs to be *complete* enough to be physically realistic.

Our objective is to find the limits where the typical model describing mixed-sediment river morphodynamics is physically realistic (and thus usable). We aim at providing a model that is usable outside these limits.

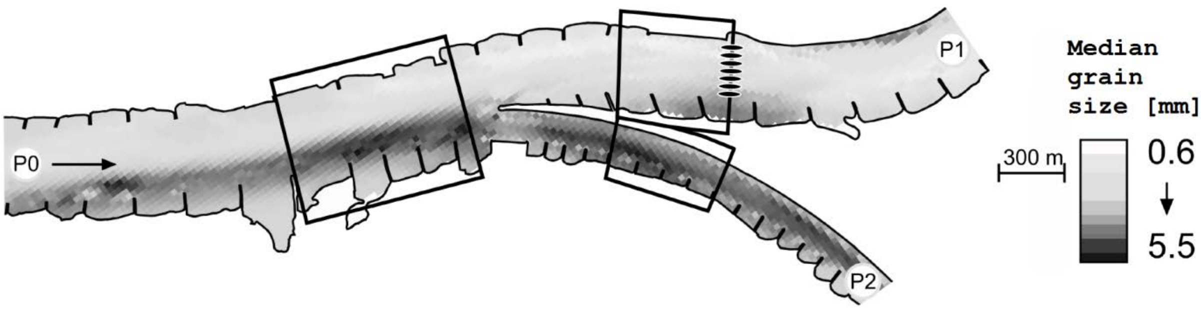


Figure 1: Median bed surface grain size in the Pannerdensch Kanaal, ca. 5 km downstream from the nourishment place (adapted from Frings, 2007).

Results

We have conducted a mathematical analysis of the typical model for mixed-sediment river morphodynamics and we have found that the current approach fails to reproduce the natural phenomena in some circumstances. More specifically, it becomes mathematically ill-posed over a quite wide domain. We have created a tool to numerically assess the results of simulations in order to know whether those are well or ill-posed. We have conducted a preliminary laboratory experiment to gain insight on the mechanisms that are important under those conditions where the typical model is ill-posed and we have found that a cyclic behavior of entrainment of substrate material and coarsening of the bed surface occurs that is not considered in the model. We have found that a modification of the time scales regularizes the mathematical model, which makes it recover its well-posedness. In Figure 2 we plot the bed elevation and bed surface mean grain size with time, and the vertical stratification at the end of two runs. Run I (first row) uses the typical model and in Run II (bottom row) we apply a regularization strategy. Otherwise, the conditions are the same in both runs. Please note how ill-posedness manifests as physically unrealistic oscillations in the solution while the regularized model provides a well-posed solution.

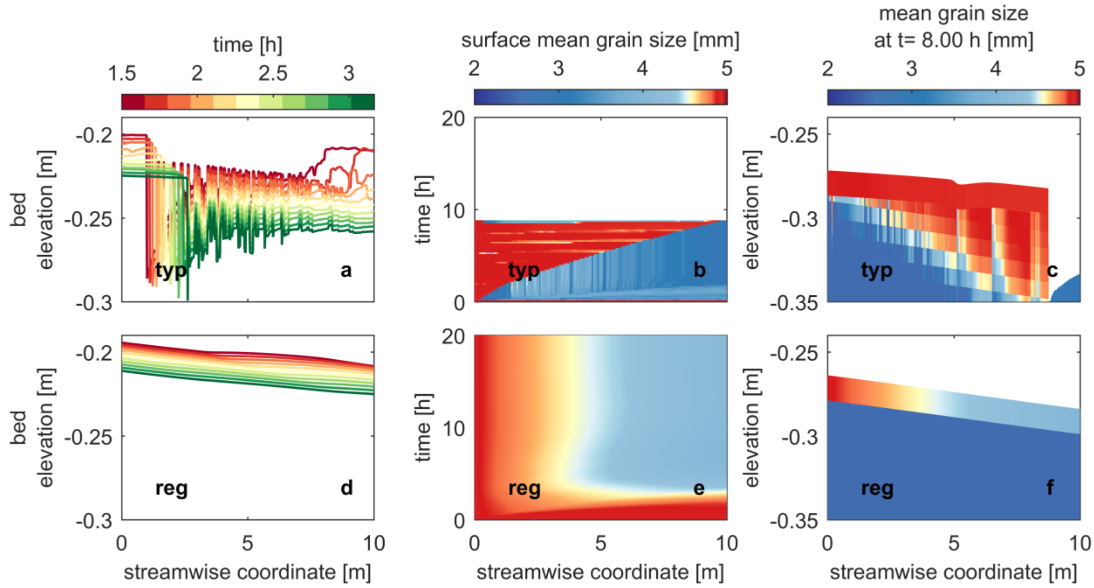


Figure 2: Bed elevation, surface mean grain size, and stratigraphy at the end of two runs. Run I (top) is computed with the typical ('typ') model and Run II (bottom) with our regularization strategy ('reg').

Unfortunately the regularization strategy is not generically applicable and there is a range of physical phenomena that cannot be modelled, for instance, some cases of mixing related to dune growth.

Next steps

Our results show that the current approach to model river morphodynamics with mixed-sediment is not appropriate over a wide domain. For this reason we are currently involved in implementing our numerical tool into the software package Delft3D to assess well or ill-posedness in numerical simulations more efficiently.

Although we can assure that our regularization technique provides a well-posed solution, laboratory experiments are needed to assess whether the solution is also physically realistic. We are about to run laboratory experiments to assess (a) the physical mechanisms that prevail under mathematically ill-posed conditions, and (b) under which conditions the regularization strategies provide physically realistic results. Eventually, we aim at providing a model that is generically well-posed. To this end we will, rather than a regularization strategy, develop a conservation model for mixed-sediment that shows an improved description of the prevailing physics.

References

Frings, R. (2007) *From gravel to sand*, PhD thesis, Utrecht University, The Netherlands.

Lanzoni, S. & Tubino, M. (1999) Grain sorting and bar instability *Journal of Fluid Mechanics, 393*, 149-174.

Parker, G. & Klingeman, P. C. (1982) On why gravel bed streams are paved *Water Resour. Res., 18*, 1409-1423.

Seminara, G.; Colombini, M. & Parker, G. (1996) Nearly pure sorting waves and formation of bedload sheets *Journal of Fluid Mechanics, 312*, 253-278.

Sternberg, H. (1875) Untersuchungen über Längen- und Querprofil geschiebeführender Flüsse *Zeitschrift für Bauwesen, 25*, 483-506 (in German).

Yatsu, E. (1955) On the longitudinal profile of the graded river *Eos, Transactions American Geophysical Union, 36(4)*, 655-663.

D2: Numerical modelling of sediment management measures

Project:	**D: Sediment nourishment and floodplain monitoring**
Researcher:	Liselot Arkesteijn
Project leader:	Dr ir Astrid Blom
Supervisors:	Dr ir Astrid Blom, dr ir Robert Jan Labeur, dr Ralph Schielen, Prof dr ir Wim Uijttewaal (promotor)
Started:	12 2014
Contract until:	12 2018

TU Delft

e.c.m.m.arkesteijn@tudelft.nl

Research description

In the last decades the bed of the Rhine river has been degrading at a rate of a few centimeters per year. This has several negative side-effects on the long term, especially for the navigability of the river since an uneven degradation may lead to humps in the river bed. Recently Rijkswaterstaat started a large scale nourishment field experiment near the German-Dutch border to counteract this. Sediments will be supplied and tracked during the coming years to obtain more experience for the future design of (potentially) regular measures. Although the first effects may become visible already during the coming few years, the trend of the long-term effects will only become clear after at least several decades, since morphodynamic changes are typically slow and take place on a timescale of hundreds or thousands of years. Numerical models can be used to assess this long-term impact of sediment management measures. For instance for the nourishments in the Rhine, the DVR module of Delft3D has been used to forecast the effects (Ottevanger et al. 2015). In this particular model, assumptions are made associated with neglecting the dynamics of flood waves to make computation times feasible. In other models the river is schematized to a 1D channel, excluding two and three dimensional processes such as the flow in river bends or bifurcations. We aim to assess the relevance of flood waves and multiple dimensions for long term morphodynamic changes, and address their implications associated with the applicability of numerical models. This will lead to guidelines on the possible simplifications in the modelling of flood waves, and the necessity to use higher-dimensional models (2D-3D) to accurately model the longitudinal trend of the river profile.

Results

Over time rivers tend to an equilibrium state in which the morphodynamic state is dynamic (varies around a mean state). The prediction of a long-term trend using a numerical model can only be accurate if the system tends to the correct equilibrium state. Therefore we have studied the equilibrium profile in general and the performance of numerical models with respect to this as a first step towards defining possible simplifications in the modelling of flood waves and consequent morphodynamic changes. In literature, mainly steady equilibria have been described, whereas under the influence of a cycled hydrograph or yearly passing flood waves, an equilibrium state can only be dynamic. Figure 1 (black lines) shows a schematic of the mean state of a river in a dynamic equilibrium. For a prismatic channel, the longitudinal profile may roughly be divided in three sections: the hydrograph boundary layer (HBL), the quasi-normal flow section, and the backwater segment. In the quasi-normal flow section, the equilibrium profile can be reasonably approximated using analytical expressions that consider the flow to be uniform at all time (e.g. De Vries 1974). The profile computed using these expressions is indicated by the grey line. During this project we have developed a fast algorithm to numerically approximate the dynamic equilibrium state in the backwater segment. For mildly sloping rivers like the Rhine, the length of this zone can be up to a few hundred kilometers. The algorithm is yet limited to single-branch systems, as the partitioning of sediment over two downstream branches at a bifurcation is not easily accounted for.

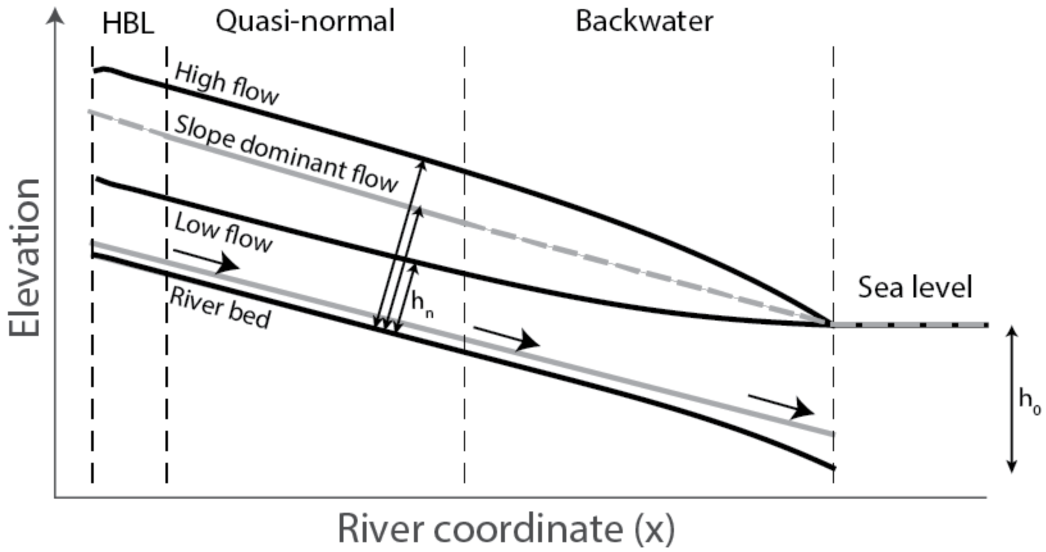


Figure 1. Mean longitudinal river equilibrium profile, divided into three zones. 1) Hydrograph boundary layer (HBL): Transition region in the river where a mismatch in sediment transport rate and transport capacity is corrected for; 2) Quasi-normal flow segment, characterized by a constant slope; 3) Backwater segment, characterized by the presence of backwater curves during high and low flow, resulting into a predominantly convex bed slope.

Flood waves that travel down the river tend to diffuse slowly while propagating downstream. The river's hydrograph therefore changes along the river. The various simplifications that are made in numerical models tend to either overestimate or underestimate the amount of wave dampening. The main preliminary conclusion with respect to the applicability of existing numerical models and techniques is that mainly discharge variability and an accurate local hydrograph are of importance for accurate predictions. Including the full wave dynamics, i.e. accurate velocities and their spatial gradients is less relevant. The numerical models that have been used to forecast the outcome of the nourishment pilot in the Rhine consider no wave dampening due to the application of a schematized hydrograph (see Yossef et al. (2006)), which is justified since the actual flood wave dampening in the Dutch part of the Rhine is limited because most quick fluctuations in the hydrograph have already dampened to a large extent in the upstream part of the river.

A second requirement for the applicability of a simplified model is a similar response in time to perturbations to the system, such as the spreading of nourishments, a correct response to base level change, and eventually the time the river needs to find a new equilibrium. The performance of several simplified flow models with respect to these issues was tested using numerical model runs. The test cases are idealized, though the river characteristics and hydrograph are inspired by the Rhine characteristics. Figure 2 shows the results for a nourishment case. Model A that describes the wave propagation explicitly was compared to Models B and C that discretize the hydrograph and assume an instantaneous propagation of flood waves through the entire domain. In Model B a variable discharge is considered, such that no dynamic wave is present but the water level in the river is lifted as a plateau. In Model C a constant steady discharge is prescribed, such that there is no flood wave at all. Similar as for the equilibrium situation it was found that Model B with an accurate discharge variability performs relatively well in comparison to Model C that entirely eliminates the wave.

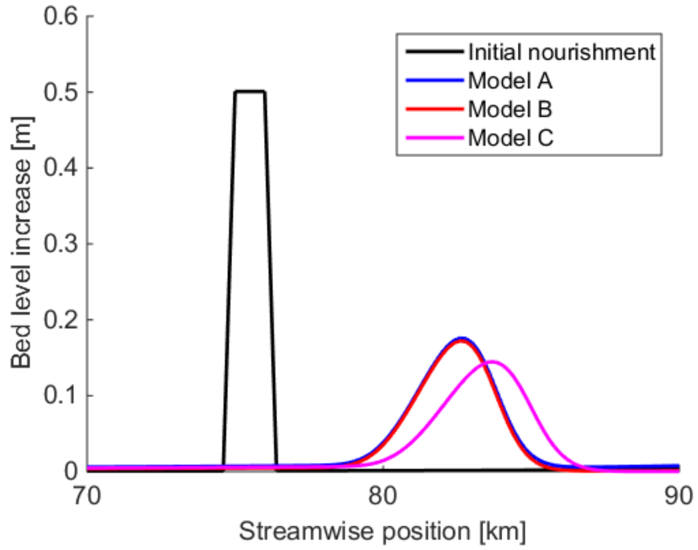


Figure 2. Nourishment displacement after 1 year. Flow model A: Full wave model. Flow model B: Schematized hydrograph with 20 modes. Flow model C: Steady discharge. (Weerdenburg, 2016).

Next steps

Our analysis of the equilibrium state is still ongoing and so far we have mainly considered situations where the sediment was assumed to be uniform. An important matter in the design of nourishment measures, however, is the range of grain sizes of the mixture. Next we therefore aim to extend the analyses and the approximation algorithm to include mixed-size sediments. Furthermore, we will extend the approximation to include a more realistic channel geometry by allowing for width variations. Technically this is possible, but the accuracy of the approximation needs to be studied. After that, the study of the accuracy of simplified models in time will be extended to obtain more general conclusions. Finally, after describing the role of flood waves, the focus will shift towards the required number of dimensions of a model, i.e. choosing for a 1D/2D/3D model or a combination of them.

References

De Vries, 1974. Sedimenttransport, *lecture notes f10,* Delft University of Technology.

Ottevanger, W., Giri, S., Sloff, K., 2015. Sustainable Fairway Rhinedelta II. Deltares report 2015.

Weerdenburg, R. van , 2016. Morphodynamic modeling of sediment augmentation in rivers. Bsc Thesis Delft University of Technology, June 2016.

Yossef, M., Jagers H., van Vuren, S., Sieben, A., 2008. Innovative techniques in modelling large-scale river morphology. In *River Flow 2008, Proceedings of the International Conference on Fluvial Hydraulics*, Çeşme, Izmir, Turkey, Sept. 3–5, 2008.

E1: Floodplain rehabilitation: linking processes to patterns

Project:	**E: Ecosystem services of floodplain rehabilitation**
Researcher:	Valesca Harezlak
Project leader:	Prof dr Suzanne Hulscher
Supervisors:	Dr ir Denie Augustijn, dr Rob Leuven, dr Gertjan Geerling, prof dr Suzanne Hulscher (promotor)
Started:	01 2015
Contract until:	12 2019

UNIVERSITY OF TWENTE.

v.harezlak@utwente.nl

Research description

In contrast to cyclic rejuvenation of riparian vegetation along natural flowing rivers, vegetation in floodplains along regulated rivers in the Netherlands matures to its climax succession stage. This climax stage is associated with high hydraulic roughness and low water storage capacity and hence, it can jeopardize water safety during high water discharges. To avoid such situations, various types of measures are taken, like clearing floodplain trees, floodplain excavation and grazing. However, the efficiency of those measures is not well understood. Moreover, other ecosystem services of floodplains are often overlooked. The latter is a missed opportunity, as water safety may be combined with other ecosystem services, such as biodiversity, carbon sequestration and water purification. Increasing knowledge on how to influence floodplain processes to guarantee water safety, while accounting for other ecosystem services, supports cost-efficient floodplain management. Therefore, the aim of this research is 1) to develop a process based, spatially explicit model that provides insight in dominant steering processes of floodplain vegetation development, and 2) to translate this vegetation development into multiple ecosystem services. To apply the model to a broad range of lowland rivers, the model set-up will be generic.

Progress

A process-based model requires insight into the dominant processes and their interactions. Many so-called process based models simulate the abiotic processes on vegetation: certain abiotic conditions lead to certain, but fixed, vegetation types. They do not consider the biotic processes like competition for nutrients, water and/or light or the effect of grazing. Additionally, the vegetation types in those partly process-based models are region specific: the dominant plant species of that area are used. For model applications in other regions, the types of vegetation in the model should be replaced.

A literature study revealed that certain plant species can establish populations somewhere because they possess specific characteristics (life history traits). It is the combination of traits that determine species fitness along environmental gradients and as such explain why certain species are dominant at one location but absent or scarce at another site. So, it is not a species that is an indicator for the steering processes at a location, but the combination of traits a species encompasses. The combination of traits has been studied intensively and has led to, among others, the ‘leaf economics spectrum’. This spectrum explains how traits trade-off under different water, nutrient, light regimes. Recently, a ‘root economics spectrum’ has been developed and additionally, effort has been put to link above ground to below ground traits. The knowledge gained from the literature forms the backbone of the model of this research.

It became evident that in certain case studies the trait approach was successful while in others it was not. For this reason and because of model calibration and verification purposes, fieldwork has been and will be carried out over a period of three years. The fieldwork focusses on 30 small plots (circa 1.0 -1.5 m^2) that are spread over three Dutch floodplains. In those plots, abiotic conditions, like soil moisture, soil nutrient and organic content, have been and will be monitored, as well as plant species and traits, such as growth form, clonality, specific leaf area and C, N and P content of the leafs (Figure 1).

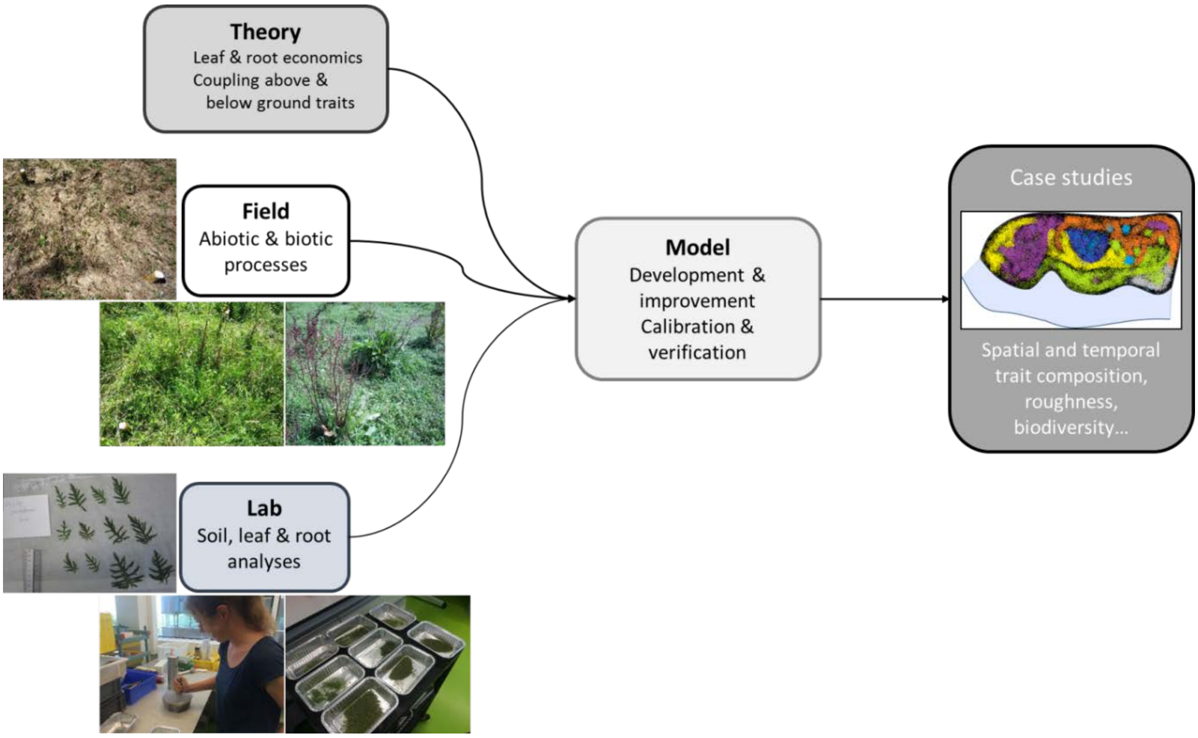


Figure 1: Schematic representation of the work.

Next steps

In the coming period, the focus of the work is on the analyses of the data retrieved from the field: how can it be linked to the conceptual models presented in literature? And how can it be used to increase insight in the dominant steering processes in Dutch floodplains? For that, the process-based model, still in its infancy, is taken a step further. Alternating between field and model work has proven to stay critical on what a useful, applicable model is and what kind of data is actually needed from the field. Hence, the work results in 1) analyses on trait-field data for increasing the knowledge on dominant processes of vegetation development in Dutch floodplains and 2) model development to simulate vegetation development and the concurrent ecosystem services in Dutch floodplains.

E2: Ecosystem services: assessing ecological assets and liabilities of river systems

Project:	**E: Ecosystem services of floodplain rehabilitation**
Researcher:	Remon Koopman
Project leader:	Dr Rob Leuven
Supervisors:	Dr Rob Leuven, dr ir Denie Augustijn, dr Rob Lenders, Prof dr Ton Breure
Started:	9 2014
Contract until:	9 2018

Radboud University

kkoopman@science.ru.nl

Research description

Rivers and their floodplains encompass numerous abiotic and biotic interactions resulting in riverine ecosystem services that are beneficial to society, such as CO_2 sequestration, flood mitigation and water supply (Fig. 1). The sustainable use of these services can contribute to cost-effective river management. Appropriate quantification of riverine ecosystem services is an important prerequisite for sustainable river management. This project focusses on the biophysical quantification of spatial and temporal development of ecosystem services in river-floodplain systems in relation to natural processes and management measures.

The aim of the project is to deliver novel and sound indicators, valuation approaches and model tools in BIO-SAFE for quantification of ecosystem services in river-floodplain systems (stand-alone version, including users guide and training programme for potential users).

Figure 1: Ecosystem services categorized according to the CICES classification (provisioning, regulating and cultural services) and including an extra category: abiotic resources (Source: ANK).

Results

The first paper of this project shows that quantitative approaches for biophysical linkage of ecosystem services to landscape classification systems are scarce, especially for river systems [1]. In some case studies ecosystem services' indicators have been linked to landscape classes, however data on the

spatiotemporal development of these indicators in relation to landscape changes was limited [1, 2, 3]. Six landscape classification systems appeared to be suitable for biophysical quantification of spatiotemporal development of riverine ecosystem services in BIO-SAFE (e.g., CORINE and REC - River Ecotope Classification).
Biomass production of woody and non-woody vegetation is the first ecosystem service that is quantified and linked to the REC. The biomass production of different vegetation roughness classes in floodplains along the rivers Waal, Nederrijn and IJssel were calculated for the years 1997, 2005, 2008 and 2012. Overall the biomass production shows a decreasing trend over the years, especially for floodplains along the Waal owing to flood defence measures. This trend is predominantly caused by a decrease in the biomass production of non-woody vegetation, since woody biomass production remains relatively constant over the 15 year period (Fig. 2) [4].
First results on the annual carbon sequestration of riparian vegetation in European riparian areas are already available. The average annual carbon sequestration potential of above-ground vegetation was calculated, based on Net Primary Productivity data, for different CORINE classes, which are present in European river systems. Classes related to Forests and natural areas had the highest carbon sequestration potential in three climate regions: Mediterranean, Temperate continental and temperate oceanic.

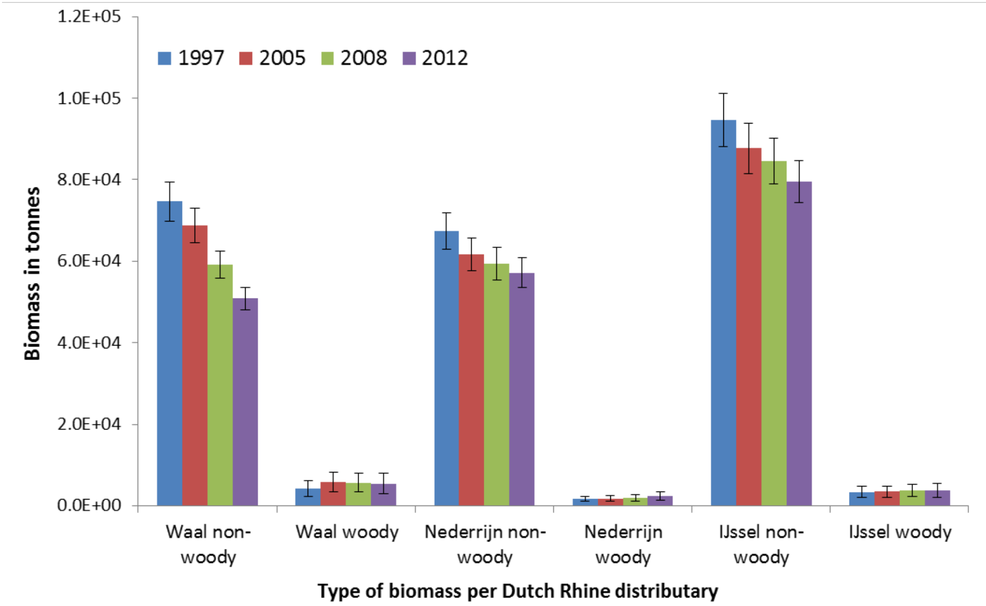


Figure 2: The woody and non-woody biomass production of floodplains along three main river Rhine distributaries in the Netherlands (Waal, Nederrijn and IJssel). Woody indicates the amount of woody biomass (hard wood and soft wood from trees and shrubs) produced; non-woody indicates the amount of non-woody (grass, reed, crops) biomass produced. Error bars indicate standard deviation [4].

Next steps

The next step is to quantify other ecosystem services. Further study is needed to link CO_2 sequestration to the REC, to quantify it at smaller scales and to determine the trade-offs with biomass production. Subsequently, other ecosystem services will be quantified and trade-offs between them are assessed and applied in various case studies.

References

[1] Koopman, K.R. Augustijn, D.C.M., Breure, A.M., Lenders, H.J.R. and Leuven, R.S.E.W. (2016) Landscape classification systems for quantifying spatiotemporal development of riverine ecosystem services. *The International Journal of River Basin Management*, (revised version submitted).

[2] Koopman, K.R., Augustijn, D.C.M., Breure, A.M., Lenders, H.J.R. and Leuven, R.S.E.W. (2015a) How to quantify spatial temporal development of riverine ecosystem services. I.S. rivers – integrative sciences and sustainable development of rivers, June 24, 2015, Lyon (France).

[3] Koopman, K.R., Augustijn, D.C.M., Breure, A.M., Lenders, H.J.R., Leuven, R.S.E.W. (2015b) Suitability of landscape classification systems for quantification of ecosystem services in BIO-SAFE, Book of Abstracts: Bridging gaps between river science, governance and management, NCR-days 2015, Radboud University, Nijmegen, October 1-2, 2015.

[4] Koopman, K.R., Augustijn, D.C.M., Breure, A.M., Lenders, H.J.R., Stax, S., Straatsma, M.M. and Leuven R.S.E.W. Quantifying biomass production for assessing ecosystem services on riverine landscapes (in prep).

E3: Floodplain monitoring

Project:	**E: Ecosystem services of floodplain rehabilitation**
Researcher:	Wimala van Iersel
Project leader:	Dr Rob Leuven
Supervisors:	Dr Menno Straatsma, dr Elisabeth Addink, prof dr Hans Middelkoop (promotor)
Started:	11 2014
Contract until:	11 2018

Universiteit Utrecht

w.k.vaniersel@uu.nl

Research description

Riverine floodplains are important for hydrodynamics, ecology, and socio-economics. This variety of functions can be assessed within the framework of *ecosystem services* (ESS). Some fluvial ESS can be computed based on landscape ecological units, such as ecotopes. ESS vary with spatial and temporal scale, and should be documented with a matching ecotope map. However, there is presently no comprehensive multi-temporal scale ecotope classification, and no multi-scale monitoring methods exist that can automate mapping of ecotopes. Further need for monitoring arises from the flood reduction measures that are currently implemented, which lead to a high spatio-temporal variability of the ecotope distribution.

The main scientific challenge is to determine a system of multiscale ecotope classes that can be linked to ESS, and that can be monitored using remote sensing data. The focus of this research is on ecotope mapping using remote sensing methods on different spatial scales. This project explores different types of remote sensing data acquired from different platforms, ranging from mobile terrestrial, via airborne, to spaceborne (Fig. 1). Temporal aspects of vegetation development, such as phenology and succession, will be included in the classification. From the perspective of the current river management, our methods will provide an integrated, multiscale monitoring toolbox which will serve river managers and planners alike.

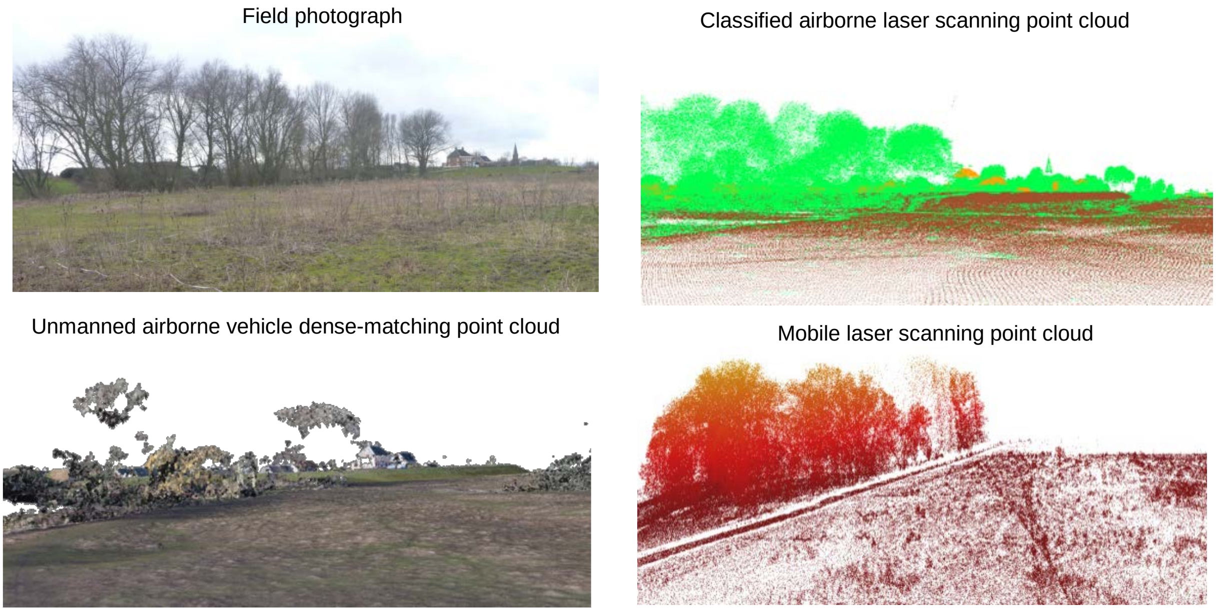


Figure 1. Examples of the different data types used to monitor vegetation in this study. Study area is Breemwaard floodplain along the River Waal. [1]

Results

A multi-temporal field study in the Breemwaard floodplain combined with unmanned airborne vehicle (UAV) imagery showed that the remotely sensed height models are accurate enough to obtain temporal height profiles of low floodplain vegetation over the growing season. Vegetation height can be predicted over time from the height models in leaf-on conditions [2]. Moreover, vegetation greenness derived from spectral information and vegetation height show typical hysteresis behavior in the UAV data for different vegetation types. These are promising results for increasing the classification accuracy of low floodplain vegetation.

Indeed, multi-temporal data input greatly improved classification accuracies (CAs) of grassland and herbaceous vegetation classes in floodplains [3]. Input data contributing most to this high CAs are the spectral and vegetation height layers covering the extremes of the vegetation phenology. Most classification errors occurred in classes without seasonal changes, such as water and paved surfaces. In addition, confusion between natural and production grassland remained. This may be resolved by using thematic data on management of these grassland areas, but preferably this may be resolved by fine-tuning the classification method.

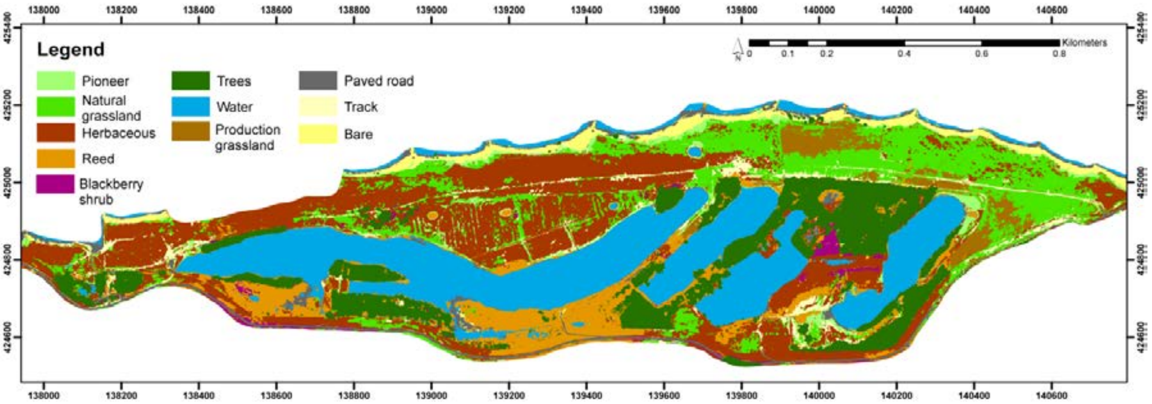


Figure 2 Classification of the Breemwaard based on multi-temporal UAV spectral and height data [3].

Next steps

The flexibility of UAVs for data collection offered a higher temporal resolution of monitoring ESS and spatio-temporal habitat dynamics. However, monitoring the floodplains large catchments with UAV imagery is an impossible task. Therefore, the main next step will be to up-scale the region of interest to a river reach of 100+ km. The input data for the development of monitoring methods on this scale will be collected from spaceborne platforms. We will focus on high spatial resolution multispectral data and synthetic aperture radar (SAR) data. We will then also address monitoring a-biotic properties of floodplain lakes.

References

[1] W.K. van Iersel, M.W. Straatsma, E.A. Addink, H. Middelkoop (2015) Monitoring vegetation height of grassland and herbaceous vegetation with remote sensing. In: Lenders et al., Bridging gaps between river science, governance and management. Book of Abstracts NCR-Days 2015 Nijmegen, October 1-2, pp. 123-126.

[2] W.K. van Iersel, M.W. Straatsma, E.A. Addink, H. Middelkoop (2016) Monitoring vegetation phenology of grassland and herbaceous vegetation with UAV imagery. In: Proc. XXIIIrd congress of the ISPRS

[3] W.K. van Iersel, M.W. Straatsma, E.A. Addink, H. Middelkoop (2016) River floodplain vegetation classification using multi-temporal high-resolution colour infrared UAV imagery. In: Proc. GEOBIA 2016 congress

F1: Improving river management by estimating model uncertainty

Project:	**F: River governance: uncertainties, participation and collaboration**
Researcher:	Koen Berends
Project leader:	Prof dr Suzanne Hulscher
Supervisors:	Dr Jord Warmink, prof dr Suzanne Hulscher (promotor)
Started:	03 2015
Contract until:	12 2019

UNIVERSITY OF TWENTE.

k.d.berends@utwente.nl

Research description

Over the past thirty years, there has been a growing conviction in the scientific community that predictions of numerical models must always be accompanied by analyses of sensitivity and uncertainty. This should be no different for the hydraulic models for simulating river systems. However, in practice uncertainty analysis encounters severe problems, both from a scientific and practical point of view.
From a scientific point of view, it is poorly understood how to perform uncertainty analysis for models applied to dynamic systems, especially in the case of impact assessment. While calibration and validation are performed on historical datasets, the model is often applied to a modified version of the same system. A prime example is impact assessment of river interventions, as for example in the *Room for the River* policy program (see Figure 1).
From a practical point of view, uncertainty analysis is extremely taxing on computational resources. In this project we explore alternative ways to perform uncertainty analysis. These alternative methods will be tested against the framework mentioned above: where are the limits of their application in a changing river system?
By pursuing these challenges, this research project contributes to the advancement both the scientific and practical state-of-the-art, by building on experiences of the past decade of modeling changing river systems to provide new methods for river management of the future.

Figure 1. The Room for the River project (shown: 'Dijkverlegging Nijmegen-Lent') is a prime example of a changing river system. Source: Google, DigitalGlobe, Aerodata International Surveys.

Results

Calibration is generally performed to increase the performance of river models – and decrease uncertainty of their predictions. As a first step to deeper understanding about how model performance and model uncertainty behave under change, *Berends et al. (2016)* studied the sensitivity of model performance to systematic change by human intervention for an idealized case study. Their analysis suggests several mechanics that lead to additional uncertainty and decreasing model performance. These mechanics can lead to spurious expectations of accuracy for traditional impact assessment and should therefore be taken into account when communicating model predictions. A deeper analysis of these mechanics is currently being carried out by modeling a stream-scale experimental flume under various conditions. Early results demonstrate the limitations imposed on predictive power by calibration and highlight the necessity of effective validation. Finally, progress has been made on the use of *physics-based emulators* for computationally less expensive uncertainty analysis. Early results of using an emulator for uncertainty estimation of sedimentation in an estuarine system suggest a hopeful outlook for combining emulators in combination with a transfer function.

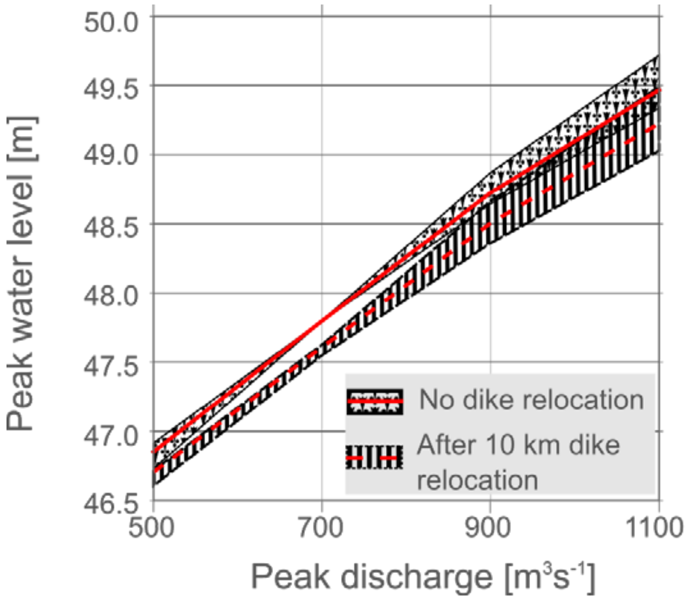


Figure 2. Solid & dashed center lines: ground truth; Envelopes: model results obtained with multiple parameter sets. Both extrapolation and modification (by dike relocation) were found to attribute to increasing uncertainty in prediction. Source: Berends et al. (2016)

Next steps

We will focus on two paths, which are closely linked. In the first place, we will further study the issue of model performance and changing river systems for a real case study – for which data is currently being gathered. Secondly, we continue to pursue the use of physics-based emulation for river systems. Advances are already being made in the generation of such an emulator, to be followed by applied uncertainty analysis at a later stage. However, we expect that the potential use of the emulator will be constrained by similar challenges as described in *Berends et al. (2016)* – thus highlighting the common thread in this project. The final aim of this project is to provide new methods for uncertainty estimation, to improve river management of the future.

References

Berends, K.D., Warmink, J.J., Hulscher, S.J.M.H. (2016), *Sensitivity of model performance to systematic change: an idealized study of river hydraulics*. Submitted to *Water Resources Research*

F2: Public perception and participation

Project:	**F: River governance: uncertainties, participation and collaboration**
Researcher:	Dr Laura Verbrugge Wessel Ganzevoort
Project leader:	Prof dr Suzanne Hulscher
Supervisors:	Dr Riyan van den Born
Started:	04 2014 (Laura) 03 2016 (Wessel)
Contract until:	10 2017 (both)

Radboud University


l.verbrugge@science.ru.nl
w.ganzevoort@science.ru.nl

Research description

Gaining knowledge on local perceptions of and public support for landscape interventions helps water managers to make better informed decisions and provides a fruitful starting point for initiating public participation. Subproject F2 focuses on stakeholder perceptions and opportunities for stakeholder participation and collaboration in river management. Our study area is a ten-kilometre stretch of the Waal between Tiel and Ophemert, where the traditional groynes have been replaced by longitudinal dams. This intervention has split the river into a main and secondary channel, which is projected to improve flood safety and discharge capacity, reduce maintenance costs, and create opportunities for inland shipping, recreation and nature development. The aim of this study is twofold:

(1) we monitor how local residents, recreational anglers and boaters, and shipping professionals (Fig. 1) perceive the changes that come about due to the construction of the longitudinal dams;

(2) we explore how and to what extent local stakeholders can be involved in monitoring the effects of the dams, and initiated a pilot project for participatory monitoring. The results from this project will inform the design of public engagement strategies.

Figure 1. An overview of the stakeholders included in the study (clockwise): local residents (Source: Beeldbank RWS), recreational boaters and anglers, and professional shipping (Source: L. Verbrugge).

Results

Throughout 2014, largely before the dams were constructed, a first round of surveys was carried out among the stakeholder groups: residents (N = 1102), recreational anglers and boaters (N = 75) and shipping professionals (N = 88). The survey tapped into perceptions of the river landscape, attachment to the area, views on nature, and expectations of the longitudinal dams (Verbrugge & Van den Born, 2015). The results showed that residents from the villages were more strongly attached to the river landscape than those living in the city of Tiel, and anglers were more dependent on it than any other group. Regarding the planned longitudinal dams, shipping professionals and especially anglers had negative expectations of the measures, mostly due to safety and accessibility concerns respectively, whereas boaters and residents had positive expectations, especially regarding flood safety. Based on stakeholder perceptions and their level of concern, we initiated two pilots on participatory monitoring (PM) in the spring of 2016. First, a group of volunteer anglers is participating in fish monitoring by reporting their catches in the study area (Figure 2). Second, a number of shipping professionals is involved in measuring fuel usage, travel time and safety aspects on the trajectory. These pilots have been initiated in close collaboration with the Royal Dutch Angler Association and Royal BLN-Schuttevaer (shipping), Rijkswaterstaat and research institutes.

Figure 2. Measuring catches at a fishing competition organized by the regional angling association HFMN (Source: HFMN).

Next steps

At the end of 2016 a second round of surveys will be sent out to all the stakeholder groups, in order to analyse how the groups differ in their perceptions of the landscape now that the dams have been constructed, and how their perceptions have changed in the past two years. The next steps in the participatory monitoring pilot are to report on the data collection and participants' experiences; to share these results among the participants and involved partners; and to evaluate the PM pilot using both process and outcome criteria.

References

Verbrugge, L. N. H., & Van den Born, R. J. G. (2015). *Beleving langsdammen: nulmeting onder bewoners, sportvissers, recreatievaarders en binnenvaartschippers*. Prepared for Rijkswaterstaat Oost-Nederland by the Radboud University, Nijmegen [in Dutch]. 105 p.

Verbrugge, L.N.H, G. Ganzevoort, J.M. Fliervoet, K. Panten & R.J.G. van den Born (in review). Implementing participatory monitoring in river management: the role of stakeholders' perspectives and incentives. *Journal of Environmental Management*.

Verbrugge, L.N.H. & R.J.G. Van den Born (in review). The role of place attachment in attitudes towards re-landscaping river interventions. *Environment and Behavior.*

F3: Collaboration

Project:	**F: River governance: uncertainties, participation and collaboration**
Researcher:	Jan Fliervoet
Project leader:	Prof dr Suzanne Hulscher
Supervisors:	Dr Riyan van den Born, prof dr Toine Smits (promotor)
Started:	04 2014
Contract until:	04 2016

Radboud University

j.fliervoet@science.ru.nl

Research description

Around the world, governments have implemented integrated river management projects to realize multi-functional floodplains which support flood protection, nature restoration, recreation and agricultural activities. This integrated approach increased collaborative arrangements between diverse levels, sectors and actors in the planning and implementation phase, also called collaborative governance. Now that the implementation of the projects is about to be finalized, a new phase is called for, the floodplain maintenance phase. Maintaining multi-functional floodplains includes several tasks, such as monitoring, developing ecological infrastructure and coordination of maintenance activities. However, it is unclear how collaboration will continue in the maintenance phase. The aim of this subproject is to shed more light on the complexity of the current collaborative, cross-boundary interactions between governmental and non-governmental actors regarding the maintenance of Dutch floodplains. This complexity is caused by the multi-stakeholder approach, which includes diverse expectations, ideas and conflicting goals, such flood protection versus nature restoration. Therefore, this subproject F3 explores the underlying visions, frames and relationships among stakeholders in the context of collaborative governance. This will result in recommendations to improve collaborative initiatives to maintain flood protection and nature goals in an integrated way.

Figure 1. A flooded floodplain of the river Waal in 2012, which also functions as a nature reserve (source: Fliervoet).

Results

To get insight in the actor relations and the level of intensity of their collaborations a social network analysis was used that focus on flood protection (A) and / or nature objectives (B) in the context of floodplain maintenance (Fliervoet et al. 2016). The analysis showed that both networks were heterogeneous and well-connected, but only a few ties existed between the flood protection group and the nature organizations (respectively group 1 and 4 in Figure 2A and B). This fragmentation has been increased by the discontinuation of a public coordinator which represented one of those links (Crd1).

Based on interviews, the analysis of the stakeholder's frames about collaborative objectives and membership structures showed two things. Firstly, the stakeholders envisioned a structure that reflected a clear separation between public and private actors. Secondly, the results showed the diversity of collaborative objectives held by the stakeholders (Fliervoet & van den Born, 2016). To solve the tension between a desire for multi-stakeholder participation and the reality of a fragmented and single-objective maintenance process, we suggest that the joint planning approach as a working methodology could be introduced in the current collaborative processes to maintain Dutch floodplains, in other words to apply a 'Joint Maintenance Approach' (Warner, Fliervoet & Smits, 2016).

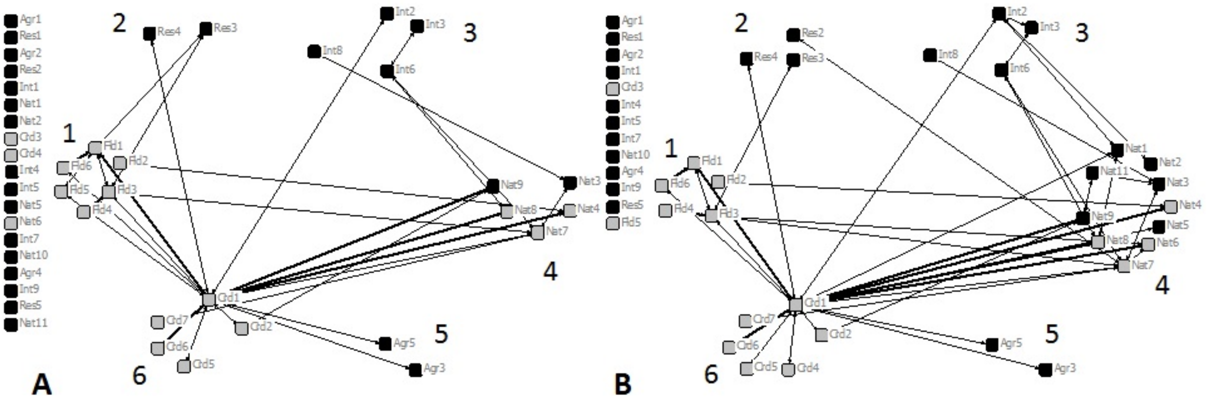


Figure 2: Social networks based on the monthly and weekly reciprocal ties concerning flood protection objectives (A) and nature objectives (B). Numbers indicate groups of organizations; 1: flood protection; 2: research institutes; 3: special interest groups; 4: nature; 5: agriculture; and 6: spatial planning (Fliervoet et al., 2016).

Next steps

The next step is to finalize a journal article, to be submitted to the international journal of Water Resources Management with the working title; *"a stakeholder's evaluation on collaborative processes for maintaining multi-functional floodplains: a Dutch case study"* (Fliervoet, van den Born and Meijerink). Based on interviews, this article explored regional stakeholder's frames with respect to their incentives, the collaborative process itself, distribution of tasks and outcomes about collaborative maintenance. All respondents were involved in a pilot project, called *"Rijnwaarden"*, which dealt with setting up a new collaborative process for integrated floodplain management, but was unsuccessful in realizing collaboration and integrated floodplain management. The findings show the practical multi-level, multi-sector and multi-actor challenges for effective collaborative governance to maintain multi-functional floodplains.

References

Fliervoet, J.M., Geerling, G.W., Mostert, E. and Smits, A.J.M. (2016). Analyzing collaborative governance through social network analysis: A case study of river management along the Waal River in The Netherlands. *Environmental Management* 57 (2): 355-367. http://link.springer.com/article/10.1007/s00267-015-0606-x

Fliervoet, J. M. & Van den Born, R. J. G. (2016). From implementation towards maintenance: sustaining collaborative initiatives for integrated floodplain management in the Netherlands. *International Journal of Water Resources Development*, DOI:10.1080/07900627.2016.1200962

Warner, J.F., Fliervoet, J.M. and Smits, A.J.M. (Oct. 2016). Towards a joint maintenance approach for floodplain management in the Netherlands: tensions and possibilities. In: Margerum R.D. & Robinson C.J., *The Challenges of Collaboration in Environmental Governance: Barriers and Responses*. Edward Elgar publishing, UK, 336 pages.

G1: Virtual River

Project:	**G: Communicating programme outcome: knowledge base, visualisation and Virtual River**
Researcher:	Robert-Jan den Haan
Project leader:	Prof dr Suzanne Hulscher
Supervisors:	Prof dr ir Mascha van der Voort, prof dr Suzanne Hulscher
Started:	10 2014
Contract until:	10 2019

UNIVERSITY OF TWENTE.

r.j.denhaan@utwente.nl

Research description

The objective of the Virtual River project is to develop a serious gaming environment as a tool for actors to explore river management strategies in a collaborative fashion.

River management has become increasingly complex in recent years. The Room for the River (RvdR) program for example, incorporated a multifunctional approach to space. The RvdR projects have been executed to increase the space for water. At the same time, the projects aimed to enhance spatial quality – i.e. including functions such as nature, housing, recreation and business (Van Stokkom et al., 2005) – implying that multiple interests were taken into account. Combined with the decentralised approach of RvdR, this implied the introduction of more actors with their own objectives to the decision-making processes. River management is therefore a complex socio-technical system as it combines this socio-political component with the inherent technical uncertainties – i.e. river dynamics, climate change – of a river system (Pahl-Wostl, 2006). This project intends to develop a serious gaming environment where both the socio-political and the technical complexity are included. The envisioned gaming environment supports actors in river management to collaboratively discuss, negotiate and test management strategies. This way, a level playing field can be created which facilitates constructive discussion and collaboration.

Figure 1. Serious gaming environment impression (Photo: T-Xchange)

Results

Recent activities have focused on looking beyond the RvdR program. If the RvdR program is considered to cover the exploration, plan-making and implementation phases of all projects, Dutch river management is now transitioning to a post-RvdR phase where maintenance of the RvdR interventions is central. At the same time, other programs and projects – e.g. program 'Stroomline' – are implemented in the Dutch rivers and floodplains. Various river management actors – from ministries to municipalities and from the Dutch public works authority to nature organizations – were interviewed to map the challenges they now face. In the same interviews, the participants were asked what their preferred outcome of these challenges are, what would help them achieve it and what variables they would like to experiment with while pursuing this outcome. Results of the interviews show that the actors are indeed facing new challenges in relation to maintenance. Some of these challenges can be related to maintenance not being sufficiently incorporated in RvdR planning processes, others can be related to conflicting objectives between for example water safety and nature development. As for the variables to experiment with, multiple actors mentioned scaling and organisation of maintenance on a local, floodplain or river segment scale, albeit for very different reasons.

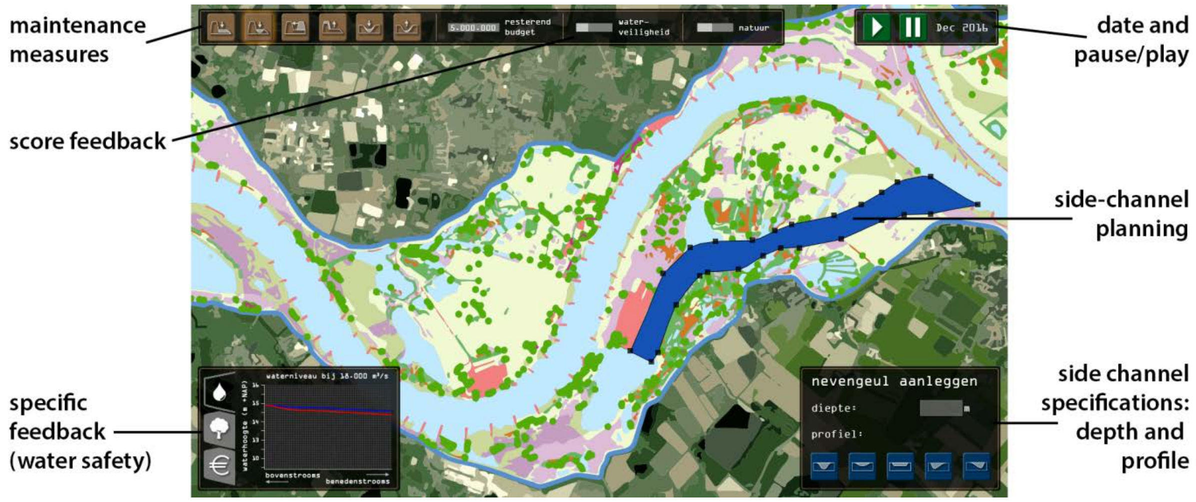


Figure 2. Paper prototype (work in progress)

Next steps

The next step is full analysis of the interview results. The results are used to develop paper prototypes for a series of concept directions (see figure 2 for an impression). Next, these paper prototypes will be evaluated in co-design sessions with a combination of interview participants and RiverCare user groups. Goal of these sessions will be to explore the paper prototypes with 3-4 participants, determine which concept direction is most interesting and what functionality they would like to have in this direction. Afterwards, a first prototype of the gaming environment will be developed and iteratively evaluated and redesigned.

References

Pahl-Wostl, C. (2006). *The importance of social learning in restoring the multifunctionality of rivers and floodplains*. Ecology and society, 11(1), 10.

Van Stokkom, H. T., Smits, A. J., & Leuven, R. S. (2005). *Flood defense in the Netherlands: a new era, a new approach*. Water International, 30(1), 76-87.

G2: Knowledge base & communication

Project:	**G: Communicating programme outcome: knowledge base, visualisation and Virtual River**
Researcher:	Juliette Cortes Arevalo
Project leader:	Prof dr Suzanne Hulscher
Supervisors:	Prof dr Suzanne Hulscher, prof dr ir Mascha van der Voort
Started:	05 2015
Contract until:	05 2018

UNIVERSITY OF TWENTE.

v.j.cortesarevalo@utwente.nl

Make explicit the context and added value of river research is essential to communicate RiverCare results. River interventions such as longitudinal training dams, side channels and water retention areas, sinking/scouring of the river bed are implemented in the Netherlands. RiverCare research is about monitoring and assessing the overall effects of these measures to reduce maintenance and optimize benefits. RiverCare knowledge is gathered in the form of analyzed data, maps, factsheets and reports. The design of a prototype knowledge platform (Figure 1) aims at effectively communicating these knowledge with end-users of different disciplines, authorities, professionals and collaborating stakeholder groups.

"The communication project offers an online platform to provide access, effectively communicate and get feedback about the interest and use of RiverCare knowledge via interactive storylines.

The platform should be useful and kept alive after our program is finished."

Knowledge base | Example storyline

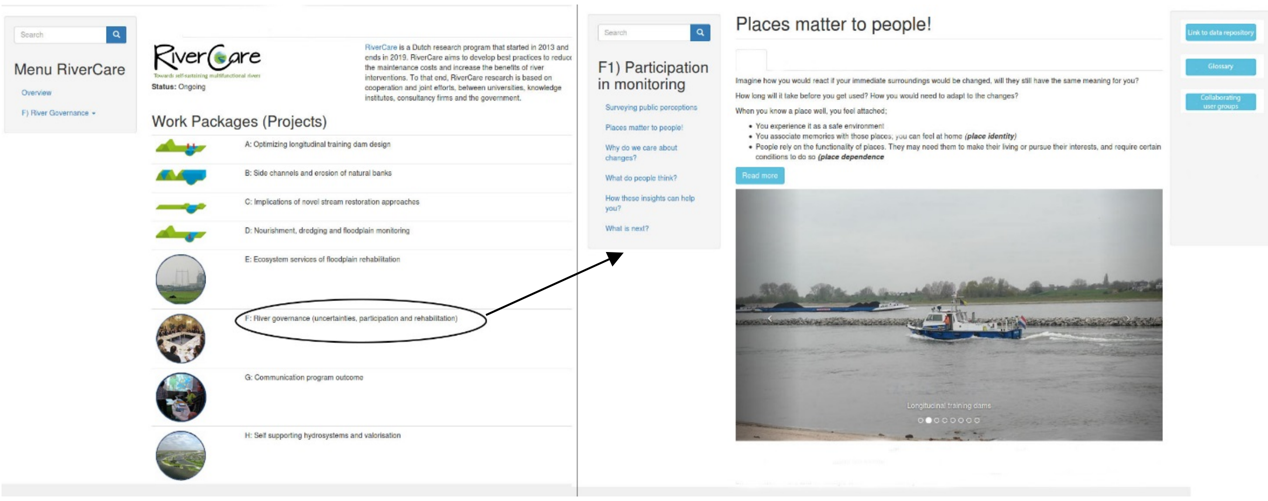


Figure 1. Link between the prototype platform and example storyline. (Source of the icons of riverine measures were taken from Room for the River).

Most recent results

The prototype design started by brainstorming with RiverCare researchers and the Communication user committee. A concept video introduced key components of online platforms to discuss during interviews between May-July/2016. Participants were related and not-related to RiverCare. Participants were members or referred by the Ecosystem Services and River Governance user committees. Interview results guide priorities for development of a first prototype. First analysis of results (Figure 2) shows that design efforts should initially focus in the storyline and data repository components. According to the Likert scale, storylines have high potential usefulness and limited previous experience, therefore, potential to do research. Knowledge base have the most potential usefulness. Querying content becomes relevant both for the agreement level and potential usefulness.

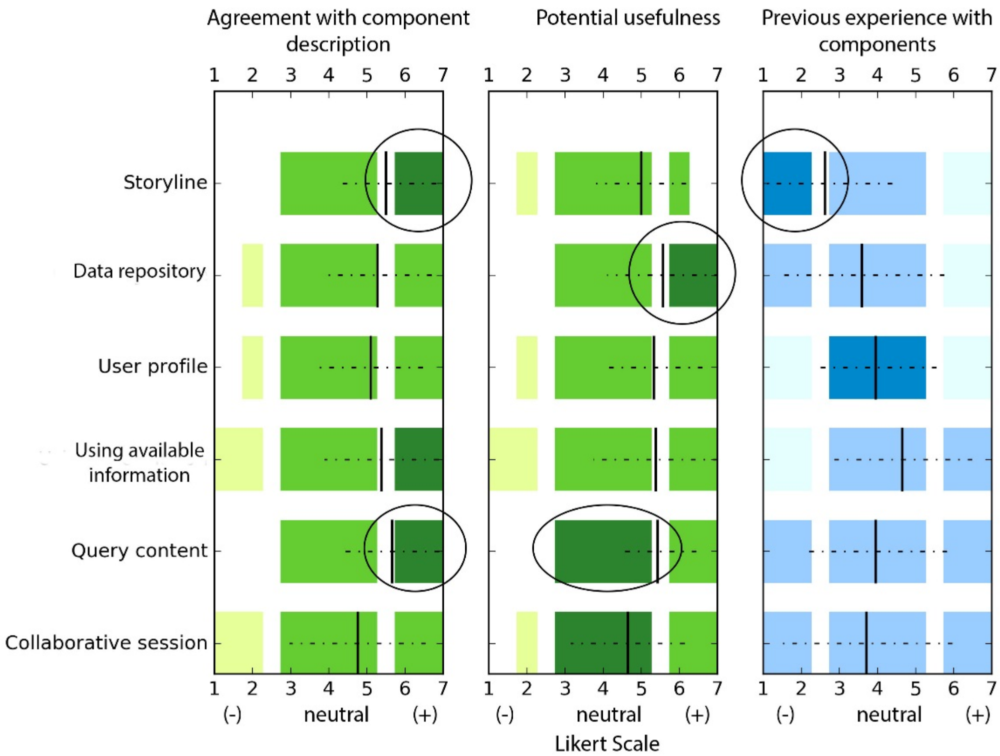


Figure 2. Mean, standard deviation and distribution of opinion of 21 interviewees about components of the video.

An example storyline is being prepared as part of the knowledge base (Figure 1). Example is about public perceptions results regarding the longitudinal training dam interventions in the Waal. An online story, overview images and interactive charts will give you glances of the results. You can fill in an online feedback about how these results can be useful for your river work or interests.

Next steps

- By presenting and discussing the progress, priorities for development will be updated.
- During a testing period at the beginning of 2017 will be evaluated the effectiveness and usefulness for better understanding of results in the example storyline.
- The platform will not be project-dependent. The prototype should illustrate how results from other projects could be potentially added, for example WaalSamen.
- Efforts to coordinate data repository are being explored via the OpenEarth DataLab of Deltares and potential collaboration with WaalSamen project.

References

Cortes Arevalo, V.J., den Haan, R.J., Baart, F., van der Voort, M., Hulscher, S (2016). The perceived value of a collaborative platform promoting a RiverCare community about the effects of riverine management. International Environmental Modelling and Software Society (iEMSs) 8th International Congress on Environmental Modelling and Software.

H1: Optimizing river management

Project:	**H: Self-supporting hydrosystems & valorisation**
Researcher:	Dr. Menno Straatsma
Project leader:	Prof dr Toine Smits, dr Gertjan Geerling
Supervisors:	Prof dr Maarten Kleinhans, prof dr Hans Middelkoop
Started:	08 2014 part time since 02 2016
Contract until:	02 2019

Universiteit Utrecht

m.w.straatsma@uu.nl

Research description

The river system consists of three interacting components, which can be characterized as the hydrosystem, the ecosystem, and the socio-economic system. In time, the autonomous development of the river system is combined with additional pressures from climate change and socio-economic developments, which necessitate landscaping measures in lowland fluvial areas. Which measures to take depends, amongst others, on the goals of the intervention, the perspective of the decision maker, and the societal preparedness for change. Multiple components of river management have been studied (Baptist et al. 2005; Haasnoot et al. 2012). What is currently not available is a 2D integrated model of the river system that can cope with hydromorphodynamic processes as well as ecological processes, such as biodiversity and ecosystem services, to support an optimal choice of landscaping measures. From a practical perspective, additional value is created by a fast and complete overview of the possible layouts of the fluvial landscape, which can inform and direct decision making processes.

Results

We quantified biodiversity changes following fifteen years of river restoration for the floodplains of an entire river delta. Protected and endangered species in seven taxonomic groups were assessed using four consecutive, detailed land cover maps and more than two million field observations on species presence. Of all 179 fluvial floodplain sections, 165 showed an increase in biodiversity. Birds and mammals showed the largest increase (+74%, +87% in saturation of their potential, respectively; Fig. 1). This showed that river restoration interventions successfully enhanced biodiversity at a large spatial scale, while decreasing flood risk.

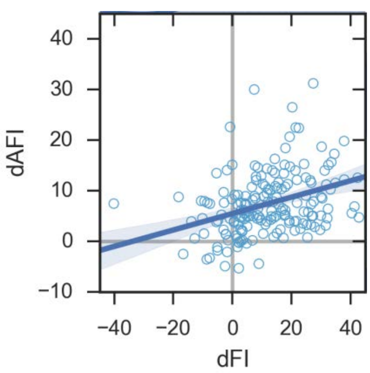


Figure 1. Changes in potential (dFI) and actual (AFI) biodiversity scores

We developed a generic GIS routine to extract the ecosystem services from existing spatial and hydrodynamic model data, and its application to historic and future fluvial landscapes in the Rhine delta. Future landscapes are generated by the routine. Currently implemented measures are: side channels, floodplain lowering, and floodplain smoothing and side channel relocation. Over the historic period, the ES increased, especially the biodiversity scores of birds and mammals improved by more than 10% due to the restoration measures (Fig. 2). One of the main drivers is the creation of new side channels, and allowing natural succession to occur to a limited extent. For the future, the scenarios showed that the overall ES score varied strongly with the type of measure chosen. Floodplain smoothing and lowering negatively impacted ES, whereas embankment relocation, and side channels increased ES scores. We conclude that the automated methods provide fast insights in the historic and future developments of fluvial ES. This is useful for the decision making and natural capital mapping, but we require increased precision in defining fluvial ES, and additional quantification and validation of the methods.

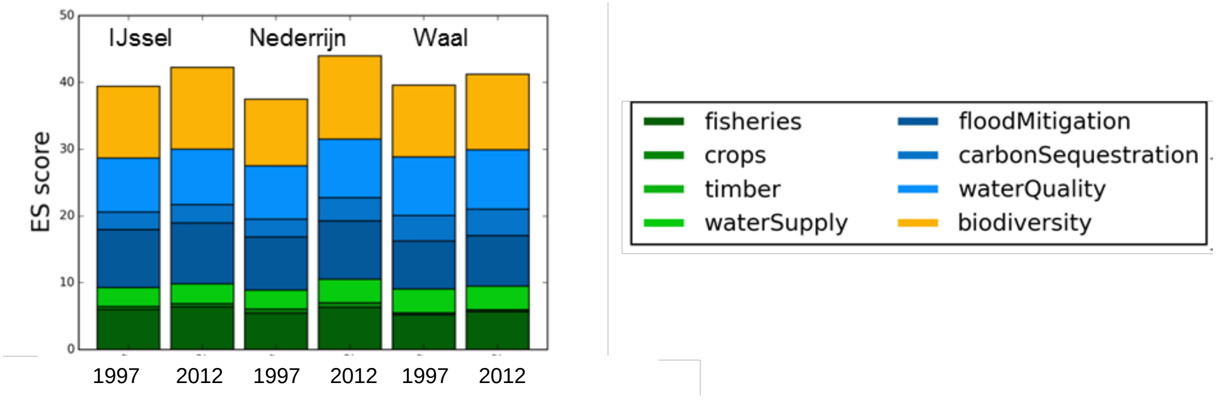


Figure 2. Temporal development of ecosystem services over the three Rhine branches between 1997 and 2012.

Next steps

We are currently setting up the model chain that enables the fast evaluation of different landscaping measures using a Monte Carlo (MC) scheme. The chain is called 'RiverScape' and it generates an arbitrarily parameterized river intervention, updates the hydrodynamic model to compute the hydraulic effects, computes the cost of each measure implementation and the benefits in terms of flood hazard reduction, biodiversity and ecosystem services. Aggregated characteristics of the realizations will be plotted in a multidimensional feature space. Optimal measures form a Pareto front in these feature spaces (Fig. 3). The Pareto front indicates the combinations of minimum cost, and minimum flood risk. Many other feasible realizations exist, but they are suboptimal. Maintenance costs and uncertainty will be added in a final step.

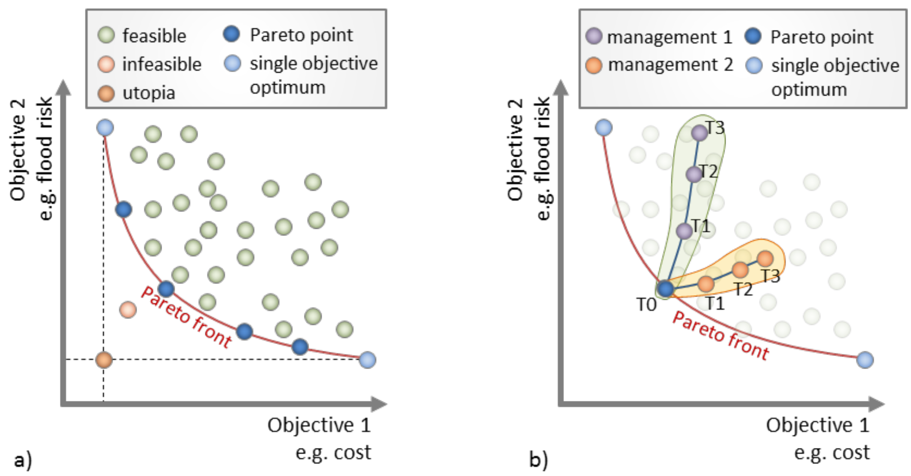


Figure 3 A) Pareto front of optimal set of river landscaping measures, b) temporal development of landscaping measures under two different management strategies with uncertainty.

References

Baptist, M.J. (2005). Modelling floodplain biogeomorphology. PhD thesis pp. 195). Delft: Delft Technical University

Haasnoot, M., Middelkoop, H., Offermans, A., Beek, E., & Deursen, W.A.v. (2012). Exploring pathways for sustainable water management in river deltas in a changing environment. *Climatic Change, 115*, 795-819

H2: 'Wealthy Waal': focus on environment and valorisation

Project:	**H: Self-supporting hydrosystems & valorisation**
Researcher:	Astrid Bout
Project leader:	Prof dr Toine Smits, dr Gertjan Geerling
Supervisors:	Prof dr Erwin van der Krabben, prof dr Toine Smits
Started:	05 2015
Contract until:	12 2019

Radboud University

astrid.bout@rws.nl

Research description

Over the past decades Dutch river management has become quite dynamic and complex. The Dutch government (Rijkswaterstaat) has to ensure the water quality, the water discharge capacity and the dimensions of the fairway in a dynamic environment with both technical and social challenges. On the one hand projects like Room for the River and the European water frame work directive made the river system more natural and dynamic. On the other hand, there are fierce organisational challenges. With an ever growing pressure to become more efficient, market oriented, transparent and collaborative.

All these developments urges organisations which are involved in river and floodplain management to explore new, creative pathways resulting in a management strategy that is based on public-private partnerships (*Rijkswaterstaat 2013*) and a more cost-efficient maintenance program.

This can be achieved by austerity and efficiency but also by finding ways to gain revenues from the river area with technical- and social innovations and utilizing ecosystem services.

This research focusses on the question *how* public parties can ensure that through private procurement of river maintenance the potential of the river area is utilized and managed optimal while still complying to their role as social player.

Figure 1. Societal stakeholders in river management source: Rijkswaterstaat (beeldbank)

Results

Rijkswaterstaat has to alter their spending on maintenance, due to budget cuts (Rijkswaterstaat, 2012). This, in combination with the public demand for sustainable development, has led to the development of the program Self Supporting River System (SSRS) in the eastern part of the Netherland. The SSRS program, as part of the Dutch Topsector Water, actively seeks different types of relationships and rules within the sector to address the societal challenges that are summarized by the increasing mismatch between the (present) static approach of river maintenance in a complex and dynamic environment.

The main goal is to make and keep river management affordable, reliable and sustainable in a socially desirable way. The financial ambition of SSRS is a 40% cut on their spending on river maintenance by 2021 (Rijkswaterstaat, 2011).

One of the main projects of the SSRS program is part of the performance contract IJsseldelta – Twentekanalen. The goal of the Annex Learning Space SSRS is to work together on improvement- and investment proposals on vegetation and sediment management. The starting point of the Learning Space to offer possibilities to cooperate on an equal level in the golden triangle of businesses, researchers and government. This way cooperation could facilitate the proposing and the joint development of innovative ideas.

Figure 2. Pilot: vegetation management of riverbanks and groins with sheep (foto Yuri Wolf, Rijkswaterstaat)

Next steps

The next steps will be:

- Write/complete (policy) review article about the program Self Supporting River Systems (ex durante evaluation). This will also include some new data collected from interviews with stakeholders.
- Study “Riverine biomass as ecosystem service” about the use of biomass as ecosystem service by public organizations. An analysis of the current practice of biomass utilization in river management regarding the organisations ambitions and conditions.
- Start case-study “Learning space IJsseldelta- Twentekanalen”. This case-study will be done by preforming a thought-experiment and game simulation. Focus on: market orientation, risk-sharing, public-private partnerships, innovation.

References

Rijkswaterstaat. (2011b). Roadmap Self Supporting Rivier Systeem 2021 - Innoveren met water.

Rijkswaterstaat. (2012). Bezuinigingen Rijkswaterstaat op beheer en onderhoud. Retrieved 28-01, 2016, from http://www.rijkswaterstaat.nl/over-ons/nieuws/nieuwsarchief/p2012/09/Rijkswaterstaat-bezuinigt-164-miljard.aspx

"Voor Rijkswaterstaat is co-creatie de toekomst | Cobouw.nl ..." 2013. 22 Jul. 2014 <http://www.cobouw.nl/nieuws/algemeen/2013/10/09/voor-rijkswaterstaat-is-co-creatie-de-toekomst>

H2: 'Wealthy Waal': focus on environment and valorisation

Project:	**H: Self-supporting hydrosystems & valorisation**
Researcher:	Swinda Pfau
Project leader:	Prof dr Toine Smits, , dr Gertjan Geerling
Supervisors:	Dr Janneke Hagens, prof dr Ben Dankbaar, prof dr Toine Smits (promotor)
Started:	05 2015
Contract until:	05 2018

Radboud University

s.pfau@science.ru.nl

Research description

The land surrounding rivers is characterized by arable soils and high vegetation growth. Where floodplains are not occupied by agricultural production, vegetation must often be removed to ensure sufficient discharge capacities during high water levels. This is especially the case in densely populated areas, such as the Rhine, delta in the Netherlands. Here, organizations concerned with the river management are interested in using biomass from riverine vegetation as ecosystem service. It is expected that biomass can be valorised as an input material in the upcoming bio-economy for the production of bio-energy or bio-based materials, thereby contributing to relevant social issues, such as the mitigation of climate change, and at the same time reducing management costs or even generate incomes. However, biomass use is not self-evidently sustainable (Pfau et al. 2014) and there are several societal dilemma's regarding the use of biomass. For example, de effectiveness of biomass applications in contributing to climate change mitigation has been heavily debated, as well as whether biomass should be used for bio-based products, rather than energy applications. When it comes to residual biomass released during maintenance measures, it is unclear which applications contribute to sustainability and how river management organizations approach a responsible use of biomass as ecosystem service.

Figure 1. Different types of riverine vegetation (left: Vecht, right: Ewijkse plaat, Waal. Photos by Swinda Pfau, 2015)

Results

Residual biomass is often proposed as a sustainable alternative to cultivated biomass, which is criticized for its effect on land use change and food production. We found that residual biomass is not a silver bullet, but can contribute to sustainability under certain conditions (Pfau 2015). Most importantly, the consequences for sustainability of changing current use have to be evaluated. Residual biomass is only seldom purely waste and regularly fulfils other functions, such as maintaining soil quality or providing habitats. The benefits of extracting residual biomass for new applications, thus causing a resource use change (RUC), have to outweigh the loss of their former function. Currently, river management organizations in the Waal area consider several RUCs for biomass released during floodplain management. For example, mowed grass that is now either left behind or composted could be used to produce pulp and paper or energy in the future. This change brings with it two important questions: which applications are the most sustainable and is a RUC justified? And how do river management organizations approach the use of ecosystem services as "entrepreneurs", ensuring societally responsible use of biomass?

Figure 2. Floodplain at Nijmegen (Photo by Swinda Pfau,2012)

Next steps

In our upcoming research we will address both questions described above. First, we will conduct an analysis comparing several scenarios of changing from current management and biomass use to options considered by river management organisations (in cooperation with Remon Koopman, E2). We will analyse both the impacts on CO_2 emissions and on economic costs and benefits of using residual riverine biomass as ecosystem service. Next, we will evaluate how river management organizations translate their ambitions regarding sustainable use of ecosystem services into practice, creating a database of river maintenance projects and analysing the procedural arrangements of biomass utilization therein (in cooperation with Astrid Bout, H2).

References

Pfau, S.F., Hagens, J., Dankbaar, B. and Smits, AJM. (2014) *Visions of Sustainability in Bioeconomy Research*. Sustainability 6 (3) 1222-1249

Pfau, S.F. (2015) *Residual Biomass: A Silver Bullet to Ensure a Sustainable Bioeconomy?*. Proceedings of the European Conference on Sustainability, Energy & the Environment 2015, 295-312.

H3: Export possibilities

Project:	**H: Self-supporting hydrosystems & valorisation**
Researcher:	Nick Leung
Project leader:	Prof dr Toine Smits, dr Gertjan Geerling
Supervisors:	Prof dr Toine Smits
Started:	10 2015
Contract until:	12 2019

Radboud University

n.leung@science.ru.nl

Research description

The Netherlands are internationally known for their knowledge, experience, engineering and innovative measures for flood protection. The Netherlands have a long history and culture in the management of water and related issues. Decades if not centuries of researching the Dutch coastal and inland water system has contributed to the development of various flood protection measures, technologies, and hydrological forecasting models and tools. With these we can closely predict extreme events, their effects and the effectiveness of prevention or restoration measures. This extensive knowledge allows us to increasingly help deal with situations abroad as well, although there are always site-specific traits. Within the RiverCare project multiple measures that have been implemented in the Dutch river systems – in the Room for the River program- are being monitored and evaluated. Subproject H3 aims to investigate the export possibilities of RiverCare knowledge - whether it is hydro-morphological insight, research on ecosystem services or novel governance aspects - by identifying marketable information and/or end products, developing guidelines for both researchers and end users to 'cash in' on the potential, and exploring the need/demand for these information products.

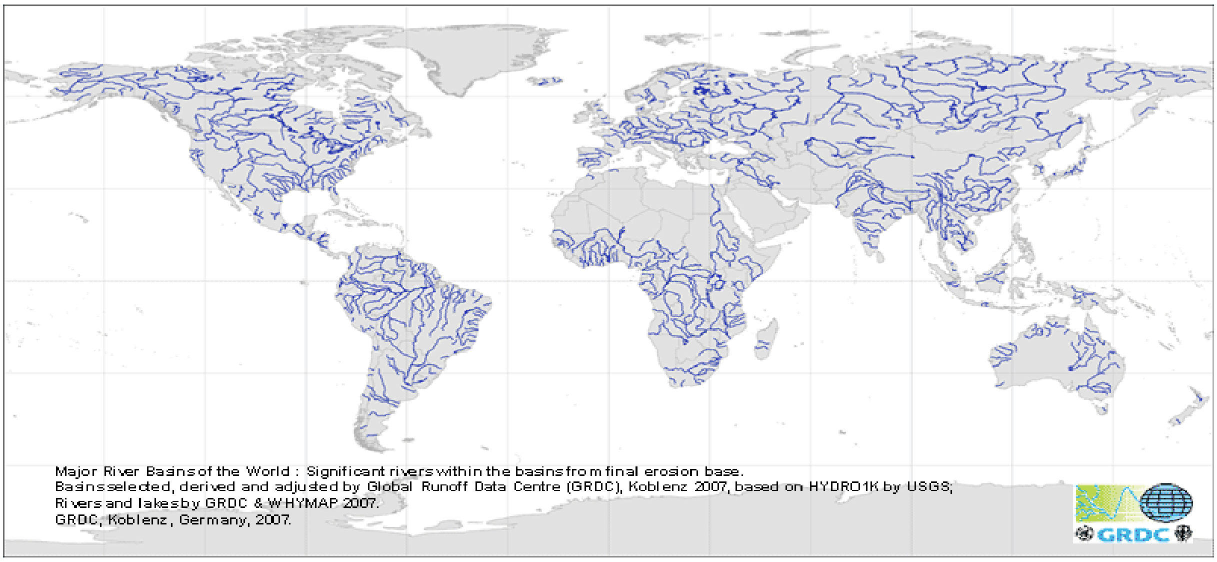


Figure1. Map of river basins on earth. Source: GRDC.

Results

In the first year we initiated an analysis of the Dutch water sector, specifically focused on the Deltatechnology (sub)sector. Deltatechnology focusses on the water availability, safety and liveability in delta and coastal areas. Our analysis resulted in a first overview of most important key players from the 'golden triangle': research institutes, governments and businesses. Each of these stakeholders plays a role in research, knowledge development, knowledge utilization and knowledge export. But how is this arranged? Do they always find the right partners to collaborate with, and how do they see their role? We'll continue this analysis through 2017.

Additionally, an overview of noticeable platforms and network organizations has been drafted. Many of such have been installed to: help promote Dutch knowledge on water-related issues globally; aid Dutch organizations in their ambitions to undertake international activities; gather signals of problems and needs abroad; and facilitate trade missions and events, thereby bringing knowledge providers and knowledge seekers together.

We started compiling a guideline document aimed to improve knowledge export, to help bridge the eternal gap between science and practice. It contains guidance on aspects like market analysis and approach, competition and strategic partnerships, cultural differences and governance structures, and funding mechanisms.

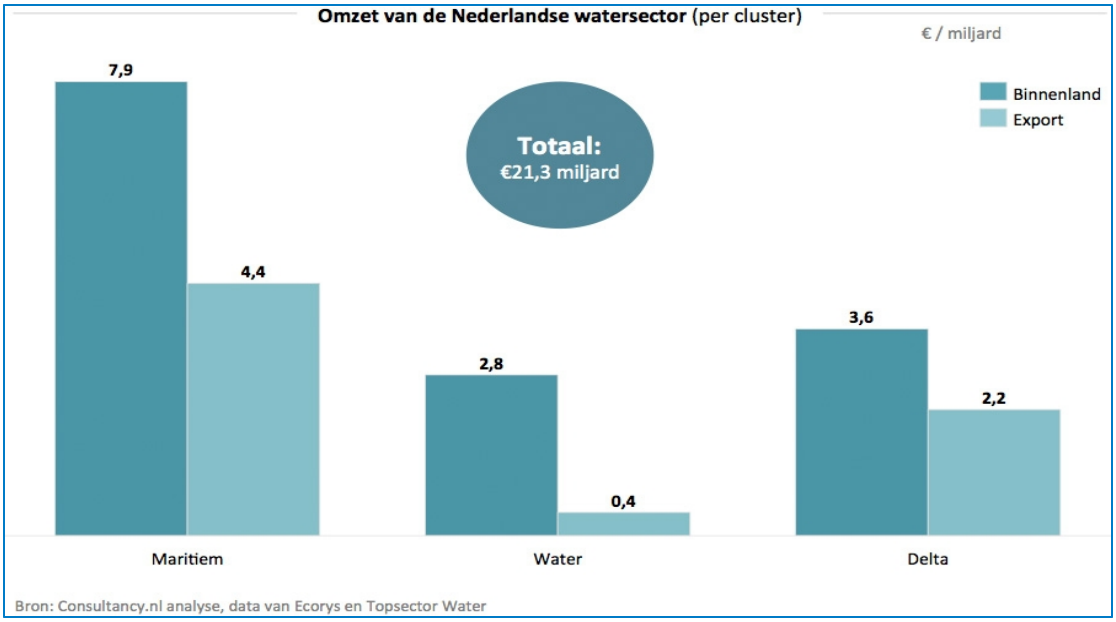


Figure 2. Graph showing revenues of the Dutch water sector in 2014. Source: Ecorys.

Next steps

The analysis of key players and network organisations shall be continued, to further explore how this 'playing field' is organized. The guidelines document will be completed using both scientific findings as well as experience from practice. More importantly, challenges related to river management abroad will be explored to get better insights in international needs for RiverCare research and results.

We will also explore the possibility to organize an event or workshop towards the end of the RiverCare program, in cooperation with existing network organisations.