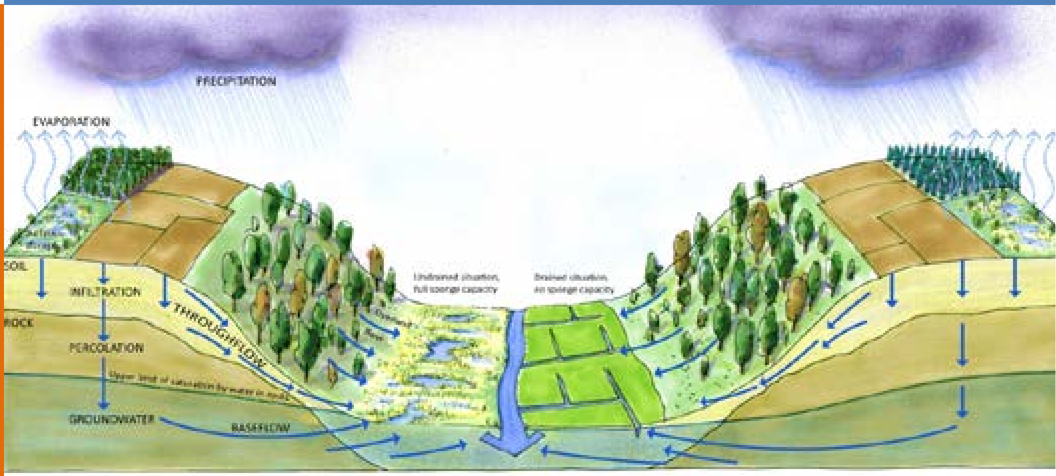
Nov 2017



Restoration of the marshes in the valleys of the middle mountains of the Rhine basin for flood and drought risk reduction

'the sponges approach'

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This project was commissioned by WWF Netherlands and Wetlands International. It has been funded by WWF Netherlands and the Michael Otto Stiftung and European Life-NGO (both granted to Wetlands International – European Association).

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We would further like to thank the following persons:

Esther Blom (WWF Netherlands until August 2016)

Frank Hoffmann (Wetlands International)

Chris Baker (Wetlands International)

Gerhard van der Top (Water Board Amstel, Gooi & Vecht)

Patrick Meire (University of Antwerp)

Erik van Slobbe (University of Wageningen)

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And all Advisory Board Members, attendees to the stakeholder meetings as wel as all interviewees (as listed in the Annexes).

Contents

Summary (EN)

Natural retention

Flood peaks on the river Rhine constitute a well-known challenge and are expected to increase due to climate change. One of the solutions already practiced is retention: during the buildup of a flood peak large quantities of water are diverted from the main riverbed, to be stored in artificial basins or specially designated polders. The water stored does not contribute to the flood peak, which as a result is lowered. This is a generally accepted approach in water management, both in the Netherlands and in Germany.

This report explores the possibilities and impacts of a different approach: Natural Water Retention. This does not involve the use of basins or polders to retain water but restored floodplains and (newly developed) wetlands and peatlands – "natural sponges" [1], at well-chosen locations in the middle-mountains of the Rhine basin. Another difference is that "natural sponges" intend to capture water at a very early stage: before it reaches (or transforms into) a stream. Technical retention basins capture water which already is part of the main river channel.

The sections below present the results of the recent study on the costs and benefits of restoration of the sponge function in wetland soils in the middle mountains of the Rhine basin for flood and drought risk reduction.

Technical analysis

1. **Potential for flood management:** up to 8% of the area covered by local catchments of tributaries to the Rhine in the middle mountains in Germany can potentially be used for increased storage and sponge restoration. A potential area in this regard means a relatively flat rural area along the stream, in a valley with a flat bottom, a u-shaped valley, which has been drained for agricultural purposes. Increased storage at this scale can have a significant effect on local peak flows. And, if implemented on several locations in a river basin, it can also have an effect on peak flows in the entire basin. . Our preliminary assessment of local catchments in the Mosel basin (such as the Prüm and Kyll) shows potential for **local peak reductions of 5 – 8 %** in the tributaries to the Rhine.

2. Within this project **a rapid appraisal method was developed which** makes it easier than before to scan (sub)basins on their potential for natural storage.

3. **Carbon sequestration:** a calculation for the Prüm catchment indicates the potential for carbon capture to be very modest.

Apart from the possible impacts (above) researched in this study, there are other effects which can be logically expected when developing 'natural sponges'. These include the following.

4. Development of 'natural sponges' improves the hydro morphological situation of streams which **improves ecological water quality** (aquatic biodiversity) and contributes to a decrease in runoff of nutrients and other pollutants into the water (chemical water quality).

5. Improving the hydro morphological situation and base flow of streams and improving water quality will result in **more biodiversity**. Extensifying agricultural production will provide better opportunities for a more diverse flora and fauna and thus improve biodiversity.

1 A natural sponge is a natural marsh- or peatland; water is temporarily stored *in* the soil as well *on* the soil. The resistance offer by the soil and rough natural vegetation prevent the water to quickly run-off into a stream or river.

6. **New business model:** introducing water services (such as sponge restoration) in which landowners are compensated for loss of agricultural production can provide **a new business model for farmers**. This would perfectly fit in the greening of the **Common Agricultural Policy (CAP)**. Without the perspective of compensation, the development of natural sponges will have a negative impact on farming because it will create wet land.

7. Natural sponges have only limited potential to **decrease periods of drought**. Contrary to flood peaks, low river discharges develop over a long period of time and the buffers in the valleys will have released most of the water stored before the lowest river discharge has been reached. In other words: natural storage will contribute to a more even distribution of water over time but for real impact on drought management, infiltration of water on the plateaus needs to be taken into account. These measures were not within the scope of this study

8. Potential other socio-economic benefits: business opportunities for recreation, tourism and housing prices potentially increase if the quality of landscape of a region improves.

Stakeholder analysis

Contact with Dutch stakeholders has been an ongoing process in the past years and has, among other things, resulted in Parliament requesting the Minister of Infrastructure and Watermanagement "… to investigate the effectiveness of natural retention in the source areas of the Rhine in the Middle Mountains in Germany and inform Parliament about this"[2]. During this stakeholder analysis German water managers at municipal, district and state level were contacted as well as some farmer organizations, NGO's, Universities and some working groups active in the respective (sub)basins .

1. Opinion, interest and (professional) background very much influence the attitude towards the sponges approach. In the first round of interviews many stakeholders remained sceptical, as they already expected the presentation of concrete facts and figures (e.g. costs, estimated area, timeframe), or because they argued that exclusively ecologically oriented measures are ineffective on a large scale. In the second phase contact persons were interviewed who were already involved in projects where nature-based solutions were included. This led to more positive feedback: these stakeholders were more positive about the impact of nature based solutions to flood management.

2. Stakeholders working for the German government think that rivers should get more retention areas in general. However, they are also cautious: just a few restored areas cannot hold the water of a 100-year flood.

3. Downstream and upstream users do not feel connected to each other. Communities are only positively minded towards the sponges approach if the restoration measure has an effect on local flood management. Effects on flood protection further downstream, e.g. in the Netherlands or in German cities such as Koblenz or Köln, does not raise much interest. For potential partners it is very hard to see the relation between small-scale local interventions and large-scale flood reduction. Local users are more willing to cooperate in local interventions with local benefits.

4. Many interviewed stakeholders seem to think that there are no spacious (U-shaped) valleys with a relatively flat valley bottom available for retention areas. They claim that

2 Motion 7 July 2016 by 2 members of Parliament: Koser Kaya and Belhaj: Motie van de leden Koser Kaya en Belhaj over onderzoek naar de effectiviteit van natuurlijke retentie in de brongebieden van de Rijn: https://www.tweedekamer.nl/kamerstukken/detail?id=2016Z14463&did=2016D29511

most valleys are V-shaped and there are very few flat plains for potential retention areas.

5. Landowners will not easily sell their land. Removing drainage systems and giving up land for water storage purposes can only be discussed if more details about compensation, duration and exact location can be provided. Apart from this financial issue, people are attached to the land itself, which would make purchase of land a difficult way to go.

6. It is easier to convince stakeholders that already are involved in nature-based solutions than it is to convince technically oriented stakeholders or stakeholders with an agricultural interest. Part of the explanation also lies in the fact that natural retention is not a simple concept and needs further elaboration. All crucial aspects of the approach need to be thoroughly explained to and discussed with stakeholders

Literature review

Literature does not provide a clear answer with regard to the effectiveness of natural retention. There are "believers" and "non-believers" – also among scientists and water managers. The review reflects the fact that current water management (research) only makes limited use of nature-based solutions such as sponge restoration. In the literature it is stated that individual natural retention projects are effective but the question whether multiple projects would be effective on a basin scale is not well researched. This issue is addressed more in depth in the report: **'Possibilities for storage? Stores of possibilities!'** It is argued that sound conclusions on the potential of natural retention can only be drawn if we gain more experience with it.

Considerations

a) Natural retention is not the panacea for flood management. However, it can play a significant role as a promising nature-based solution in the toolbox of water managers for integrated river basin management. Additional research and pilot projects are needed to further quantify the impact.
b) WWF Netherlands and Wetlands International - European Association (WI-EA) are involved in this project because they support a transboundary basin approach (i.e. taking into account the whole basin when deciding about the location of measures to improve river management) Nature based solutions provide an opportunity to combine flood risk reduction with river, floodplain and wetland restoration.
c) Restoration of sponges in itself is not new. The innovation of the approach is related to the use of sponge restoration as a nature based water management tool in the context of transboundary flood risk reduction. Linking the approach to process innovations such as the introduction of a water services system and stakeholder participation further increases the innovative character of the approach.

Recommendations

- The study demonstrates that stakeholder engagement is key in the way forward to achieve implementation. Generating stakeholder sympathy and influencing perceptions are crucial aspects to create awareness of the overlooked place and role water has in our landscape. Moreover, the sponges approach is a complex concept that can be easily misunderstood. To avoid resistance based on misunderstanding, all crucial aspects of the approach need to be constantly and thoroughly explained to and discussed with stakeholders. There seems to be a discrepancy between the perception of stakeholders about the availability of spacious (u-shaped) valleys and the results of our analysis of the potential for natural storage. The results of the present analysis should be used to support future dialogue with stakeholders.
- Mission work is still needed as social acceptance to nature-based solutions is not yet a

given. This should be seen as a necessary transition in water management in order to deal with uncertainty of climate change related precipitation developments.

- Opinions differ on the effect that sponge restoration can have on the basin scale. The difference of opinions underlines the need for integrated and transboundary knowledge sharing and exchange of perspectives on this issue. Supporters of the sponges approach can be found among water managers that embrace integrated water management and nature-based solutions. Cooperation is needed to make the local and basin-wide beneficial impacts more tangible and concrete.
- Introducing water services as a new business model will appeal to some farmers and will fit into the development towards more sustainable agriculture. It will provide an opportunity for the agricultural sector to ally itself with the natural water management approach. In addition, crossing sectoral borders and recognizing the interlinkage between cultural traditions and land use is a prerequisite to initiate dialogue on land use change.

Zusammenfassung (DE)

Natürliche Wasserrückhaltung

Hochwassersitutationen entlang des Rheins sind bereits jetzt eine große Herausforderung, welche sich aufgrund des Klimawandels höchstwahrscheinlich noch verstärken werden. Eine der möglichen Lösungen die bereits angewendet wird ist die Wasserrückhaltung: während sich das Hochwasser aufbaut wird Wasser vom Flußlauf abgezweigt und in künstlichen Becken bzw. speziell gebauten Poldern zwischengespeichert. Somit trägt das zurückgehaltende Wasser nicht zum Hochwasser bei und veringert so die Wirkung. Diese Methode ist sowohl in Deutschland als auch in den Niederlanden allgemein anerkannt.

Dieser Bericht eroiert die Möglichkeiten einer neuen Methode: die natürliche Wasserrückhaltung. Dabei wird auf Rückhaltebecken und Polder verzichtet und stattdeßen renaturierte Überschwemmungsgebiete, Feuchtgebiete und Moore, sog. "natürliche Schwämme3", in sorgfältig ausgewählten Regionen in den Mittelgebirgen des Rhein-Einzugsgebietes genutzt. Ein weiterer Unterschied besteht darin, dass das Wasser bei der natürlichen "Schwamm-Methode" bereits in einem sehr frühen Stadium, nämlich bevor es den Wasserlauf erreicht, zurückgehalten wird. Bei der technischen Methode wird das Wasser hingegen erst dann gespeichert, wenn es bereits Teil des Hauptflusses ist.

Technische Analyse

1. **Potenzial für Hochwassermanagement:** Bis zu 8% der lokalen Einzugsgebiete der Rheinzuflüsse innerhalb der deutschen Mittelgebirge könnten potenziell für den natürlichen Wasserrückhalt genutzt werden. Eine potenzielle Region zeichnet sich in diesem Fall durch einen ländlichen und relativ flachen Abschnitt entlang eine Flusses aus, welcher aufgrund der landwirtschaftlichen Nutzung entwässert worden ist. Der erhöhte Wasserrückhalt kann in diesem Ausmaß bereits einen signifikanten Effekt auf das lokale Hochwasser haben. Unsere vorausgehenden Untersuchungen zu lokalen Flusseinzugsgebieten entlang der Mosel (z.B. die Prüm und die Kyll) zeigen **potenzielle Verringerungen der lokalen Hochwasserspitzen zwischen 5 und 8%**.

2. Innerhalb des Projektes wurden eine Schnellbewertungsmethode entwickelt welche es ermöglicht Einzugsbiete und Teilbecken auf deren Potenzial für natürlichen Wasserrückhalt zu überprüfen.

3. Kohlenstoffbindung: Eine Berechnung für das Prüm-Einzugsgebiet deutet auf eine eher mäßige Kohlenstoffspeicherung hin.

Abgesehen von den möglichen Einflussfaktoren (siehe oben), die in dieser Studie analysiert worden sind, gibt es noch weitere Effekte, die bei der Entwicklung von natürlichen Wasserrückhalteflächen erwartet werden können. Dazu gehören:

4. Die Entwicklung von natürlichen Wasserrückhalteflächen verbessert die Hydromorphology und damit die ökologische Wasserqualität (aquatische Biodiversität). Außerdem verringert sich der Abfluss von Düngemitteln und anderen Schadstoffen in die Flüsse (chemische Wasserqualität).

5. Verbesserung der Hydromorphology, des Basisabflusses und der Wasserqualität führt zu einer höheren Biodiversität. Eine reduzierte Agrarproduktion fördert Flora und Fauna und verbessert somit zusätzlich die allgemeine Biodiversität.

3 Ein natürlicher Schwamm ist ein Feuchtgebiet oder Moor bei dem das Wasser temporär in, aber auch oberhalb der Böden gespeichert werden kann. Der durch den Boden und die natürliche Vegetation bedingte natürliche Widerstand verhindern so, dass das Wasser direkt in den nächstgelegenen Flusslauf abfließt.

6. Neues Geschäftsmodell: Die Einführung von Wasserdienstleistungen (wie z.B. der natürliche Wasserrückhalt), bei denen Landbesitzer für den Verlust ihrer landwirtschaftlichen Produktion kompensiert werden, könnte für viele Landwirte ein neues Geschäftsmodell darstellen und ideal in die Gemeinsame Agrarpolitik (GAP) passen. Ohne diese Kompensationen jedoch wird die Entwicklung von natürlichen Wasserrückhalteflächen einen negativen Effekt auf die Landwirtschaft haben, da Ackerflächen in Feuchtgebiete verwandelt werden.

7. Natürliche Wasserrückhalteflächen haben nur ein begrenztes Potenzial um Dürreperioden abzuschwächen. Im Gegensatz zu Hochwasserspitzen bauen sich Niedrigwasserabflüsse über einen längeren Zeitraum auf. Das führt dazu, dass die Pufferflächen in den Tälern das gespeicherte Wasser bereits abgegeben haben bevor der geringste Wasserstand im Fluss erreich wird. In anderen Worten: Über einen längeren Zeitraum gesehen trägt der natürliche Wasserrückhalt zu einer ausgeglichernen Wasserbalance bei, jedoch müsste zusätzlich noch die Versickerung von höher gelegenen Flächen mit berechnet werden, um einen direkten Einfluss der Methode auf das Dürre-Management festellen zu können. Diese Berechnungen wurden aber innerhalb dieser Studie nicht miteinbezogen.

8. Weitere sozio-ökonomische Effekte: Aufgrund der verbesserten und natürlicheren Landschaft können mehr Verdienstquellen für Erholung und Tourismus entstehen, sowie die Mietpreise einer Region gesteigert werden.

Stakeholder Analyse

Der Kontakt mit niederländischen Stakeholdern zu diesem Thema besteht seit Jahren und führte unter anderem dazu, dass das Parlament das Ministerium für Infrastruktur und Wassermanagement beauftragt hat „... die Effektivität von natürlichen Wasserrückhalteflächen in den Rhein-Zuflüssen in den deutschen Mittelgebirgen zu erforschen und das Parlament anschließend zu informieren."[4] Innerhalb der hier vorliegenden Stakeholder-Analyse wurden deutsche Wasserbeauftragte auf Gemeinde-, Bezirks- und Länderebene kontaktiert, sowie Landwirte, Nichtregierungsorganisationen, Universitäten und einige Arbeitsgruppen zu den jeweiligen Flüssen interviewt.

1. Interesse und Hintergrund der Person beeinflussen die Haltung gegenüber natürlichen Wasserrückhalteflächen. In der ersten Interviewrunde blieben viele Akteure noch skeptisch, da konkrete Zahlen (z.B. Kosten, Flächenverbrauch, Dauer) zur Methode erwartet wurden bzw. technische Methoden den natürlichen Maßnahmen generell vorgezogen werden. In der zweiten Runde wurden Stakeholder interviewt, die bereits in Projekten zum natürlichen Wasserrückhaltung gearbeitet haben. Hier war das Feedback positiver: Die Stakeholder waren dem Hochwasserschutz in Form von natürlicher Wasserrückhaltung deutlich aufgeschlossener gestimmt.

2. Akteure aus dem öffentlichen Sektor finden, dass die Flüsse allgemein mehr Rückhalteflächen brauchen, jedoch diese bei einem Jahrhunderthochwasser nicht ausreichend sein werden

3. Anlieger flussauf- und abwärts fühlen sich nicht verantwortlich füreinander. Die Gemeinden befürworten natürliche Wasserrückhaltung daher nur falls die Maßnahmen auch einen lokalen Effekt haben. Hochwasserschutz für die Niederlande oder anderen deutschen Städten wie Köln oder Koblenz, die weiter flussabwärts liegen, ist von geringem Interesse da für viele Stakeholder der Zusammenhang zwischen lokalen Eingriffen und großflächigem Hochwasserschutz unklar ist. Kooperation entsteht eher wenn es

4 Antrag vom 7. Juli 2016 von zwei Mitgliedern des Parlaments (Koser Kaya und Belhaj): Motie van de leden Koser Kaya en Belhaj over onderzoek naar de effectiviteit van natuurlijke retentie in de brongebieden van de Rijn: https://www.tweedekamer.nl/kamerstukken/detail?id=2016Z14463&did=2016D29511

um lokale Effekte geht.

4. Viele Interviewpartner meinen es gebe keine weiträumigen Täler (U-Form) für natürliche Wasserrückhalteflächen. Es gäbe dafür nur sehr wenige Regionen, der Rest sind enge Täler (V-Form).

5. Landbesitzer werden nicht einfach so ihr Land verkaufen. Das Entfernen der Entwässerungssysteme und die Aufgabe der Flächen für natürliche Wasserrückhaltung kann nur weiter diskutiert werden, wenn es mehr Details zu Kompensation, Dauer und den exakten Standorten gibt. Hinzu kommt die emotionale Bindung vieler Landbesitzer, welche die Flächen bereits seit Generationen landwirtschaftlich bestellen.

6. Es ist deutlich einfacher Akteure, die bereits in Lösungen zur natürlichen Wasserrückhaltung involviert sind, von der Methode zu überzeugen als Stakeholder, welche eher an technischen Maßnahmen glauben bzw. generell in der Landwirtschaft tätig sind. Jedoch muss hier noch deutlich mehr Aufklärung und Diskussion betrieben werden, da es kein einfach zu verstehendes Konzept ist. Alle Aspekte der Methode sollen und müssen allen Stakeholdern erklärt werden und zur Diskussion stehen.

Literaturanalyse

Die Literatur gibt keine klare Aussage in Bezug auf die Effektivität von natürlicher Wasserrückhaltung. Es gibt Unterstützer und Gegner – auch innerhalb der Gemeinde von Wissenschaftlern und Wassermanagern. Die Analyse ergibt, dass das aktuelle Wassermanagement nur einen limitierten Gebrauch von natürlichen Wasserrückhaltemethoden macht. Die Literatur bestätigt, dass individuelle Projekte zwar effektiv sind, es allerdings nach wie vor unklar ist ob mehrere Projekte gleichzeitig einen nachweißlichen Effekt auf das Einzugsgebiet haben. Diese Thematik wird im Report **'Possibilities for storage? Stores of possibilities!'** tiefer behandelt. Es bleibt aber festzuhalten, dass Schlüsse zum Potenzial der Methode zum natürlichen Wasserrückhalt erst gezogen werden können, wenn es mehr Erfahrungen gibt.

Überlegungen

a) Natürliche Wasserrückhaltung kann nicht als ausschließliche Methode für Hochwassermanagement gesehen werden. Jedoch kann diese eine signifikante Role als mögliche natürliche Lösung innerhalb eines integrativen Wassermanagements darstellen. Zusätzliche Forschung und Pilotprojekte sind jedoch notwendig.

a) Der WWF-Niederlande und Wetlands International - European Association (WI-EA) sind beides Nichtregierungsorganisationen in einem internationalen Kontext. Die Beteiligung beider Institutionen liegt daher in der Unterstützung des kompletten Einzugsgebietes (länderübergreifend, auch bei der Wahl von einzelnen Pilotregionen). Dazu zählen alle natürlichen Methoden, die Hochwasserschutz mit Fluss- bzw. Feuchgebietsrenaturierung verbinden.

a) Die Innovation der natürlichen Wasserrückhaltung ist nicht die Methode an sich, sondern versteht sich als Teil eines natürlichen Wassermanagements zur Reduzierung des länderübergreifenden Hochwasserrisikos. Die zusätzliche Verbindung mit den o.g. Prozessen (volle Beteiligung aller involvierten Stakeholder und der Einführung eines Wasserservice-Systems) verstärkt den innovativen Ansatz nachdrücklich.

Empfehlungen

- Die Studie verdeutlicht, dass die Einbindung von Stakeholdern der Schlüssel zum Erfolg einer erfolgreichen Implementierung der Methode ist. Dazu müssen mehr Sympathien für das Thema geschaffen und die Sichtweisen der Betroffenen beeinflusst werden um das allgemeine Bewusstsein zu steigern, dass Wasser als Ressource in unserer Gesellschaft darstellt. Des Weiteren ist der natürliche Wasserrückhalt ein komplexes Konzept welches sehr einfach missverstanden wird. Daher ist es wichtig alle wesentlichen Aspekte der Methode kontinuierlich und intensiv mit den Stakeholdern zu diskutieren. Es scheint außerdem eine Diskrepanz zwischen der Wahrnehmung vieler Stakeholder und der Ergebnisse dieser Studie (Potenzial für natürliche Wasserrückhalteflächen) bzgl. der Verfügbarkeit von weiträumigen Tälern (U-Form) zu geben. Die Resultate der in diesem Bericht vorliegenden Analyse sollten daher zukünftig für den weiteren Dialog mit Stakeholdern genutzt werden.

- Überzeugungsarbeit muss weiterhin geleistet werden, da die allgemeine gesellschaftliche Akzeptanz gegenüber der natürlichen Methode noch nicht vollkommen gegeben ist. Dieser Aufwand sollte als notwendiger Wandel innerhalb des Wassermanagements betrachtet werden, um zukünftige, klimawandelbedingte Unsicherheiten beim Niederschlag zu behandeln.
- Die Meinungen in Bezug auf mögliche Auswirkungen der natürlichen Methode variieren innerhalb des Einzugsgebietes. Dies bestärkt jedoch den Bedarf nach einer besseren grenzübergreifenden Zusammenarbeit, Wissenstransfer und einem regelmäßigen Meinungsaustausch. Unterstützer der natürlichen Wasserrückhaltung sind Wassermanager, die neben einem integrierten Wassermanagement auch natürliche Methoden unterstützen. Daher ist eine Kooperation aller beteiligten Länder wichtig um die positiven lokalen und überregionalen Auswirkungen handfester und konkreter zu machen
- Die Einführung von Wasserdienstleistungen als ein neues Geschäftsmodell wird einigen Landwirten zusagen und ideal in die Entwicklung hin zu einer nachhaltigen Landwirtschaft passen. Mit dieser Methode ergibt sich eine Möglichkeit für den landwirtschaftlichen Sektor sich mit natürlichen Wassermanagement zu vereinigen. Außerdem kann so der Dialog zu einem zukünftigen Landnutzungswechsel gefördert werden.

Samenvatting (NL)

Natuurlijke retentie door sponsherstel

Hoogwater op de Rijn is een bekende uitdaging en zal waarschijnlijk in de toekomst vaker voor gaan komen als gevolg van klimaatverandering. Een vaak gebruikte oplossing voor dit probleem is de inzet van retentiebekkens: als de overstromingspiek zich begint te vormen worden grote hoeveelheden water afgeleid van de hoofdstroom en tijdelijk vastgehouden in kunstmatige bekkens of speciaal daarvoor aangewezen polders. Het opgeslagen water draagt op die manier niet bij aan de overstromingspiek waardoor die wordt verlaagd. Dit is een algemeen aanvaarde aanpak in waterbeheer, zowel in Nederland als Duitsland.

In dit rapport leest u over de kansen en mogelijkheden voor een nieuwe aanpak: Natuurlijke retentie. Hiermee bedoelen we in dit geval niet het bergen van water in kunstmatig bekkens of polders, maar het vasthouden van water in herstelde overstromingsvlakten en in de bodem en vegetatie van (nieuw te ontwikkelen) wetlands en veengebieden - "natuurlijke sponzen"[5] op goed gekozen plaatsen in de middelgebergten van het Rijnstroomgebied. Het water wordt op die manier vastgehouden in de bodem en vegetatie voordat het een beek bereikt of een beek vormt. Technische retentie houdt het water pas vast als het al in het watersysteem is aangekomen.

Hieronder worden de resultaten samengevat van recent onderzoek naar de kosten en baten van "sponsherstel" in de Duitse Middengebergten– het langer vasthouden van water in bodems en wetlands als maatregel tegen overstromingen en periodes van droogte.

Inhoudelijke analyse

1. **Bijdrage aan hoogwaterveiligheid**: in het Duitse Middengebergte biedt tot 8% van het oppervlak van de beekdalsystemen die uitmonden in de Rijn kansen voor het langer vasthouden van water en voor sponsherstel. De kansen liggen in de relatief vlakke beekdalen d.w.z. in dalen met een vlakke bodem (zgn. U-vormige dalen) die worden gedraineerd voor landbouwdoeleinden. Retentie op deze schaal kan een significant effect hebben op lokale piekafvoeren. En, indien geïmplementeerd op verschillende locaties in een stroomgebied, kan dit ook een effect hebben op het niveau van het hele stroomgebied. Onze voorlopige inschatting van de beken in het stroomgebied van de Moezel (zoals de Prüm en Kyll) laat zien dat lokale piekafvoeren met 5 - 8% kunnen worden gereduceerd.

2. Binnen dit project is een **snelle beoordelingsmethode** ontwikkeld die het eenvoudiger maakt om beekdalen te scannen op hun potentie voor natuurlijke opslag van water.

3. **CO_2-opslag**: een berekening voor het stroomgebied van Prüm geeft aan dat de mogelijkheden voor CO_2-opslag waarschijnlijk zeer bescheiden zijn.

Afgezien van de mogelijke impact die in deze verkenning is onderzocht (hierboven), zijn er andere effecten te verwachten bij de ontwikkeling van 'natuurlijke sponzen'. Daaronder de volgende:

4. De ontwikkeling van 'natuurlijke sponzen' verbetert de hydromorfologie van beken. Dit leidt weer tot verbetering van de **ecologische waterkwaliteit** (aquatische biodiversiteit) en een afname van voedingsstoffen en andere verontreinigende stoffen in het water (chemische waterkwaliteit).

5 Een natuurlijke spons in dit kader is een natuurlijke overstromingsvlakte van een (beek)dal waar water wordt vasthgehouden in en op de bodem en in de vegetatie. De weerstand van bodem en vegetatie zorgt ervoor dat het water langer vastgehouden wordt en minder snel wordt afgevoerd naar een beek of een rivier.

5. Verbetering van de hydromorfologie , de permanente afvoer van beken en verbetering van de waterkwaliteit, verhoogt de **biodiversiteit**. Extensivering van de landbouw biedt ruimte voor meer soorten planten en dieren.

6. **Nieuwe kans voor de agrarische sector**: introductie van zogenaamde 'waterdiensten' (zoals herstel van natuurlijke sponzen) waarbij landeigenaren worden gecompenseerd voor verlies van landbouwproductie kan een nieuwe inkomstenbron voor boeren opleveren. Dit zou goed passen in de vergroening van het Europese gemeenschappelijk landbouwbeleid (GLB). Zonder financiële compensatie zal de ontwikkeling van natuurlijke sponzen een negatief effect hebben op de landbouw, omdat de productie vermindert.

7. Natuurlijke sponzen dragen slechts beperkt bij aan het **verminderen van droogte**. Het extra in de beekdalen opgeslagen water is al afgegeven voor de laagste rivierafvoeren zijn bereikt. Natuurlijke sponzen zullen dus wel bijdragen aan een meer gelijkmatige verdeling van water in de tijd, maar om de echte gevolgen voor droogte aan te pakken is infiltratie van water op de plateaus noodzakelijk. Die maatregel is niet meegenomen in deze studie.

8. Andere mogelijke sociaal-economische voordelen: recreatie en toerisme kunnen profiteren en woningprijzen zouden kunnen stijgen als het landschap aantrekkelijker wordt.

Stakeholder analyse

In de afgelopen jaren is er regelmatig contact geweest met Nederlandse stakeholders. Dit heeft er onder andere toe geleid dat de Tweede Kamer aan de Minister van Infrastructuur en Water heeft gevraagd: "onderzoek te doen naar de effectiviteit van natuurlijke retentie in de brongebieden van de Rijn in het Middelgebergte in Duitsland en de Kamer hierover te informeren"[6].

Tijdens de stakeholderanalyse in het kader van dit project zijn Duitse waterbeheerders op gemeentelijk, districts- en rijksniveau benaderd, evenals enkele boerenorganisaties, maatschappelijke organisaties, universiteiten en enkele werkgroepen die actief zijn in de respectievelijke (deel)stroomgebieden.

1. In een eerste ronde interviews bleven veel belanghebbenden sceptisch, omdat ze al concrete cijfers (bijvoorbeeld kosten, geschatte oppervlakte, tijdpad) hadden verwacht, of omdat ze van mening waren dat natuurlijke retentie op grote schaal ineffectief is. In de tweede fase werden mensen geïnterviewd die al betrokken zijn bij projecten waar natuurlijke oplossingen worden ingezet. Deze belanghebbenden waren positiever over het effect van natuurlijke maatregelen ten behoeve van hoogwaterveiligheid.

2. Geïnterviewde Duitse ambtenaren zijn in het algemeen voor extra retentiegebieden langs rivieren. Ze zijn echter ook voorzichtig: slechts een paar herstelde gebieden zijn niet voldoende in situaties met extreem hoge afvoerpieken.

3. Belanghebbenden bovenstrooms en benedenstrooms voelen zich niet met elkaar verbonden. Men is alleen positief als sponsherstel een lokaal effect heeft. Mensen bovenstrooms hebben weinig interesse in maatregelen die kunnen bijdragen aan minder overstromingen stroomafwaarts, bijv. in Nederlandse of Duitse steden zoals Koblenz

6 Motie van de kamerleden Koser Kaya en Belhaj over onderzoek naar de effectiviteit van natuurlijke retentie in de brongebieden van de Rijn: https://www.tweedekamer.nl/kamerstukken/detail?id=2016Z14463&did=2016D29511

of Köln. Voor potentiële partners die kunnen bijdragen aan het herstel van natuurlijke sponzen langs beken is het erg moeilijk om de relatie tussen kleinschalige lokale interventies en grootschalige overstromingsreductie te zien. Ze zijn eerder bereid om mee te werken aan lokale maatregelen met lokale voordelen.

4. Veel geïnterviewde belanghebbenden lijken te denken dat er geen ruime (U-vormige), vlakke beekdalen beschikbaar zijn voor retentie. Ze zijn van mening dat de meeste valleien V-vormig zijn, met smalle beekoevers die maar heel weinig ruimte bieden voor retentie.

5. Landeigenaren zullen hun land niet gemakkelijk verkopen. Het verwijderen van drainagesystemen en het opgeven van land voor retentie kan alleen worden besproken als meer informatie wordt gegeven over compensatie, duur en exacte locatie. Naast de zakelijke overwegingen speelt ook mee dat mensen soms een sterke band hebben met hun land en alleen daarom al niet graag verkopen.

6. Het is gemakkelijker om mensen te overtuigen die al betrokken zijn bij projecten met natuurlijke oplossingen dan agrariërs en mensen die meer technisch georiënteerd zijn. Dat komt ook omdat natuurlijke retentie geen eenvoudig concept is en nog verder moet worden uitgewerkt. Alle cruciale aspecten van de aanpak moeten grondig worden toegelicht en besproken met belanghebbenden.

Literatuuronderzoek
De literatuur over de effectiviteit van natuurlijke retentie is niet eenduidig. Er zijn “aanhangers” en “sceptici” - ook onder wetenschappers en waterbeheerders. Literatuuronderzoek laat zien dat het huidige waterbeheer slechts beperkt gebruik maakt van natuurlijke oplossingen zoals sponsherstel. De literatuur concludeert wel dat individuele natuurlijke retentieprojecten effectief zijn, maar de vraag of meerdere projecten gezamenlijk effectief zouden zijn op het niveau van een groter stroomgebied is nog niet goed onderzocht. Dit probleem komt in het rapport ‘Mogelijkheden voor berging? Bergen van mogelijkheden!’ nader aan de orde. Onderbouwde conclusies over het potentieel van natuurlijke retentie kunnen alleen worden getrokken als we er meer ervaring mee opdoen, zo wordt gesteld in de literatuur.

Overwegingen
a) Natuurlijke retentie is géén wondermiddel voor hoogwaterveiligheid. Het is echter wel een veelbelovende, natuurlijke oplossing die een belangrijke rol kan spelen in het integraal beheer van stroomgebieden. Aanvullend onderzoek en proefprojecten zijn nodig om de impact verder te kwantificeren.
b) WNF en Wetlands International - European Association (WI-EA) opereren beide in een internationale context. Zij maken zich sterk voor de stroomgebiedsbenadering, d.w.z. dat bij het bepalen van de beste locaties voor maatregelen om het rivierbeheer te verbeteren wordt gekeken naar het gehele internationale stroomgebied en niet alleen naar het binnenlandse deel ervan. Zij zijn overtuigd van de mogelijkheden die natuurlijke oplossingen bieden voor het combineren van waterbeheer en hoogwaterveiligheid met rivier-, uiterwaarden- en wetlandherstel.
c) Sponsherstel is op zichzelf niet nieuw. Maar het gebruik ervan als maatregel om hoogwaterveiligheid te verbeteren is dat wel. Het wordt in dat kader nog weinig toegepast. Het innovatieve zit bovendien ook in de integrale, internationale aanpak. Onderdeel van het idee is bv. ook het opzetten van een systeem van waterdiensten en een intensieve samenwerking met lokale partijen.

Aanbevelingen
- De verkenning laat zien dat het betrekken van stakeholders cruciaal is voor een succes-

volle implementatie van sponsherstel. Het verwerven van steun en het beïnvloeden van percepties zijn essentieel om over te brengen wat vaak uit het zich is verdwenen: de belangrijke rol die water speelt in ons landschap. Bovendien: sponsherstel is een ingewikkeld concept dat gemakkelijk verkeerd kan worden begrepen. Om te voorkomen dat misverstanden leiden tot weerstand, moeten alle cruciale aspecten van de aanpak grondig en uitgebreid worden uitgelegd aan, en besproken met, belanghebbenden. Zo lijkt er een discrepantie te bestaan tussen de perceptie van belanghebbenden over de beschikbaarheid van ruime (U-vormige) beekdalen en de resultaten van ons onderzoek Belanghebbenden denken dat die dalen er niet zijn. De analyses in het kader van dit project, die de aanwezigheid van deze dalen juist bevestigen, zouden ingezet moeten worden in toekomstige gesprekken met stakeholders.

- Acceptatie van natuurlijke oplossingen in zijn algemeenheid is nog geen gemeengoed. Om de ontwikkeling van natuurlijke oplossingen verder te stimuleren zullen we nog veel partijen moeten spreken. De ontwikkeling naar de inzet van meer natuurlijke oplossingen zien wij als een transitie in het waterbeheer die noodzakelijk is om de steeds grilliger wordende neerslagpatronen – een gevolg van klimaatverandering – op te kunnen vangen
- De meningen lopen uiteen over het effect dat sponsherstel kan hebben op stroomgebiedsniveau. Het is nodig de verschillende inzichten en kennis verder uit te wisselen in een grensoverschrijdende en intersectorale dialoog. Aanhangers van de sponzenaanpak zijn te vinden onder beheerders die een integrale aanpak en natuurlijke oplossingen omarmen. Samenwerking met die aanhangers is nodig om de gunstige effecten lokaal en op het niveau van het stroomgebied tastbaarder en concreter te maken.
- Het introduceren van waterdiensten als een nieuwe inkomstenbron zal sommige boeren aanspreken en past in de ontwikkeling naar een meer duurzame landbouw. Dit biedt de landbouwsector de kans zich te verbinden met natuurlijk waterbeheer. Doorbreken van sectoraal denken en erkennen dat landgebruik voor een deel ook cultureel wordt bepaald, zijn belangrijk om een succesvolle dialoog over veranderend landgebruik te kunnen starten.

Introduction and reader's guide

Flood peaks as well as periods of low discharges of the river Rhine already now constitute a well-known challenge in water management and are expected to increase due to climate change. One of the solutions practiced is retention: during the buildup of a flood peak large quantities of water are diverted from the main riverbed, to be stored in artificial basins or specially designated polders. The water stored in the retention basin does not contribute to the flood peak, which as a result is lowered. This is a generally accepted approach in water management, both in the Netherlands and in Germany.

This report explores the possibilities for Natural Water Retention. This does not involve the use of basins or polders to retain water but restored floodplains and (newly developed) wetlands and peatlands – "natural sponges" [7], at well-chosen locations in the middle-mountains of the Rhine basin. Another difference is that "natural sponges" intend to capture water at a very early stage: before it reaches (or transforms into) a stream. Technical retention basins capture water which already is part of the main river channel.

It is well known that wetlands and peatlands absorb – in fact require - large quantities of water so there is no doubt about the principle itself. Also, Natural Water Retention fits well with a basin approach to water management and is an example of the Green Infrastructure advocated by the EU. Additionally, restoring the natural water retention could help achieve agriculture and nature policy objectives and deliver societal benefits such as recreation, improved water quality and carbon capture. As such, it would answer to the need for innovative and integrated solutions for climate change adaptation and mitigation.

In view of this broad range of possible benefits, this study explores whether there is potential for Natural Water Retention to have a meaningful impact on a local, regional or even river-basin scale. How much space in the Rhine basin is suitable for the development of "natural sponges" and if available opportunities would be seized, what would be the possible contribution to flood control?

Apart from this introduction, this report consists of 3 parts:
part 1 describes the problem and solution in general terms: what is the water management challenge we are facing and how can natural retention contribute to the solution?

part 2 provides answers to important implementation questions: these are questions which logically present themselves on the journey from theory to implementation. The questions addressed are derived both from earlier discussions with water managers in the Netherlands as well as from interviews with German stakeholders in the context of this study. This study combined a technical approach (area needed, storage potential, costs etc.) with interviews with German stakeholders (what do they see as opportunities, what are their concerns). It is important to note that both approaches were followed in parallel: the results of the technical research were not available when the stakeholders were interviewed, nor vice versa.

part 3 is a section with annexes: in this section the results from and the methods used for the technical and stakeholder analysis are described in more detail.

7 A natural sponge is a natural marsh- or peatland; water is temporarily stored *in* the soil as well *on* the soil. The resistance offer by the soil and rough natural vegetation prevent the water to quickly run-off into a stream or river.

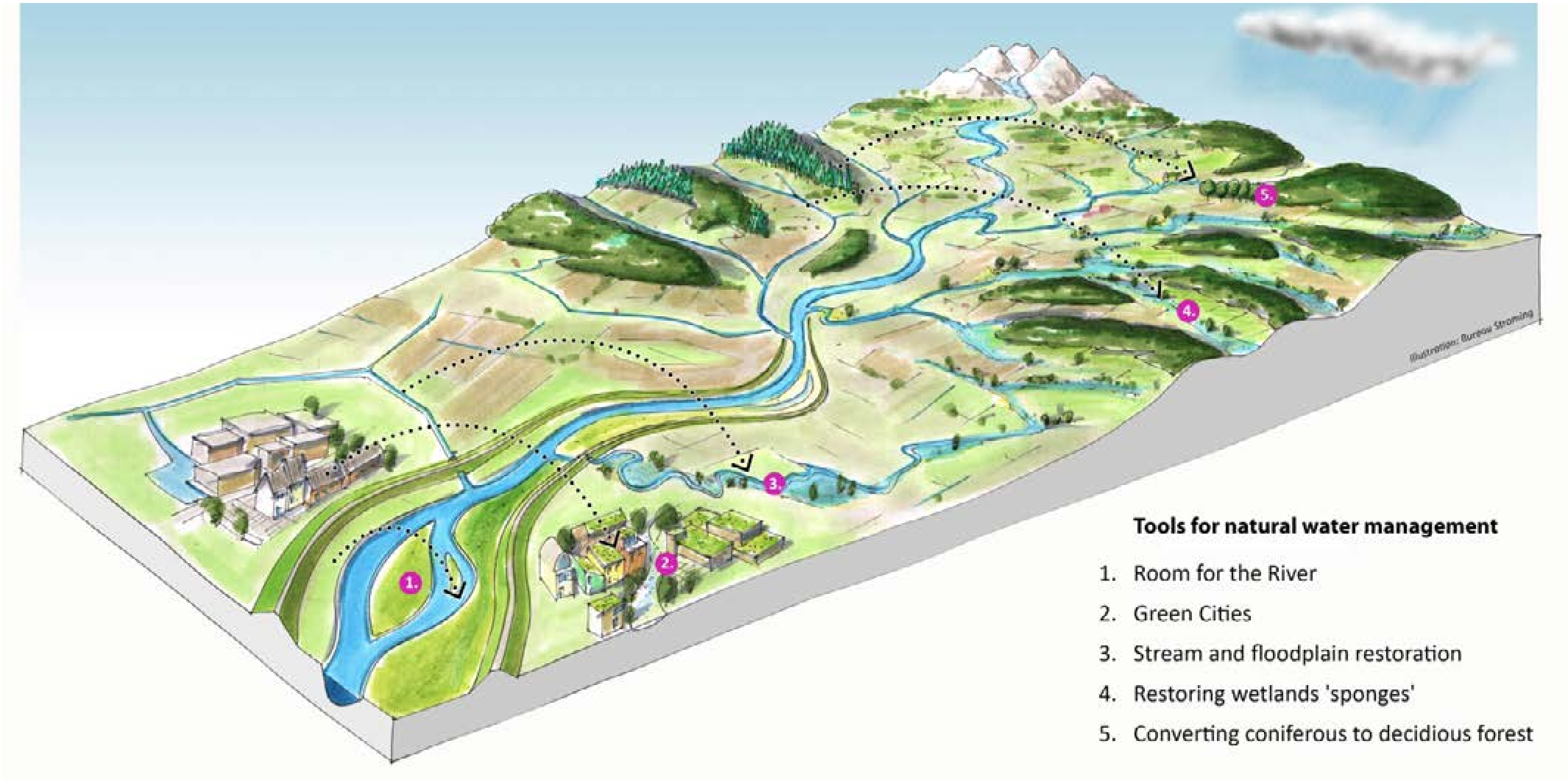

Figure 1. Tools for natural water management. In a basin approach a broad array of measures is taken which together – not in isolation – generate the desired effect: less peak flooding, shorter periods of drought.

PART I - The need for and principles behind natural storage

1. The challenge

Loss of resilience

Flooding is a natural phenomenon, characteristic of all rivers, and the basis for a rich biodiversity. So, it's not a problem, rather a blessing. Yet, this is not how most people experience it today. The reason: loss of floodplains and loss of water buffering capacity of lands and floodplains diminish the water storage capacity of river basins worldwide. This not only results in loss of wetland-related biodiversity but also increases flood peaks and periods of low discharges. On top of this comes climate change, which will result in heavier rainstorms and prolonged periods without precipitation. The developments of past and future combined, increase the risk – and in fact the occurrence – of severe impacts on society.

The Rhine is no exception. It is shorter and narrower than it was originally. Meanders have been cut off so water travels faster downstream[8], resulting in higher peak levels. At the same time the river's ability to deal with this was decreased: construction of dikes narrowed the flood plains and therefore diminished the discharge capacity. The International Commission for the Protection of the Rhine (ICPR) states that the Rhine has lost 85% of its original floodplain, including the flora and fauna depending on this. In addition, large-scale drainage took place at the flat lands, sloping hills and valleys discharging their water into (the tributaries of) the Rhine. As a consequence water travels faster downhill and downstream than ever before, causing higher flood peaks and longer periods of drought.

More disasters

Where navigation is the driving force behind most of the measures impacting the main channel of the Rhine (cutting of meanders, dredging), urbanization and agricultural practices along the river are the driving forces behind floodplain disconnection – dikes, levies – and large-scale drainage in the Rhine basin. Due to this, European regions have become less resilient to extreme situations. The result is more floods, more droughts, biodiversity loss, damage to goods and property, loss of life.

Land use planners and water managers in Europe have typically relied on hard engineered structures in an attempt to protect their communities from such "natural" hazards. However, some engineered structures, such as channelization of rivers and construction of embankments, only solve the problem locally or for a certain sector at the cost of exacerbated problems elsewhere – downstream – or in other sectors.

Nature: part of the problem, part of the solution

Modifications of natural river conditions and cultivation practices are among the most frequently mentioned pressures and threats causing ecosystem degradation and loss of biodiversity.[9] The Common Agricultural Policy (CAP) of the European Union has for decades been supporting agricultural practices that are responsible for undermining the natural resources society and nature rely on, such as freshwater resources.

At the same time it is widely recognized, also by the EU, that restoration of ecosystems brings back not only biodiversity but also ecosystem services and resilience. This principle

8 Today the water in the Rhine only needs 23 hours to flow from Base lto Karlsruhe, where in 1955 this lasted 64 hours Source: https://www.bfn.de/0324_hochwasserschutz1.html

9 European Commission (2015). The State of Nature in the European Union. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0219&from=EN

is at the core of the “sponges approach”: the (re)development of natural wetlands to temporarily store water, level off flood peaks and contribute to biodiversity. Reviving natural retention will bring us closer to a much needed robust water system, instead of moving us farther away from it. And in policy terms: it will be a concrete step in building a strong Green Infrastructure in Europe.

2. Natural retention: part of the solution

2.1 Natural retention, basin approach

There are various ways to make (restoration of) natural habitats contribute to flood control. Each part of the river basins offers its own, specific possibilities (figure 1.). Well-known approaches are the increase of the storage and discharge capacity of floodplains (“Room for the river”) or the conversion of coniferous to deciduous forests. The approach explored in this report is relatively new: natural retention. It fits in a basin approach and refers to the development of extra storage capacity in the form of marshes or peatlands. Such areas can store large quantities of water and thus act as a “natural sponge” of natural retention area.

Local water management authorities in the Netherlands and Germany are already involved in projects using natural retention; apparently natural “sponges” are an accepted tool in water management on a local level[10]. However, natural retention is not perceived as a measure that can also be effective on a regional level or even the scale of the whole river basin. And whatever the ambitions are: natural retention requires space. So one of the first questions to answer is: what is the most suitable location in the basin in terms of space and to achieve impact?

Tributaries of the Middle Rhine Region

Previous studies indicate (see box on page 24) that addressing floods on river basin scale, can best be done by the development of a patchwork of ‘natural sponges’ in the tributary catchments of the Middle Rhine Region:

- Germany’s Middle-Mountains collect more rain than other parts of the Rhine basin and therefore contributes most to flooding on a local, regional and river basin scale; (figure 2.)
- the degree of urban development along the tributaries is relatively low, so there is perspective to find the space needed for natural retention;
- land-use is relatively extensive (no vineyards, no large-scale agriculture), which is favorable from the point of view of costs (land prices) and acceptance; (figure 3.)
- favorable physical conditions: not just V-shaped valleys but also U-shaped valleys with the relatively flat valley floors needed for natural storage.

10 The ‘Deltaplan Hoge Zandgronden’ in the Netherlands and ‘Aktion Blau Plus’ in Germany both include projects that are similar to the sponges approach

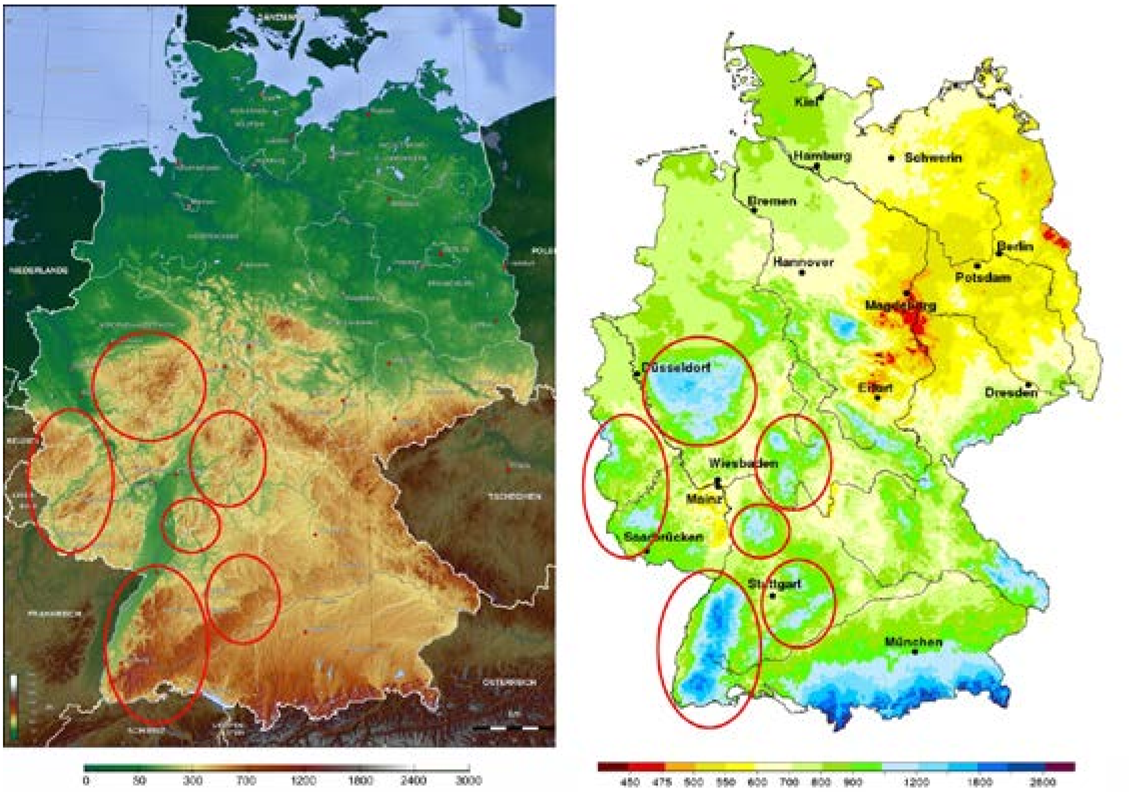

Figure 2. Precipitation patterns in Germany show that the Middle Mountains receive relatively more rain than other regions in the Rhine basin

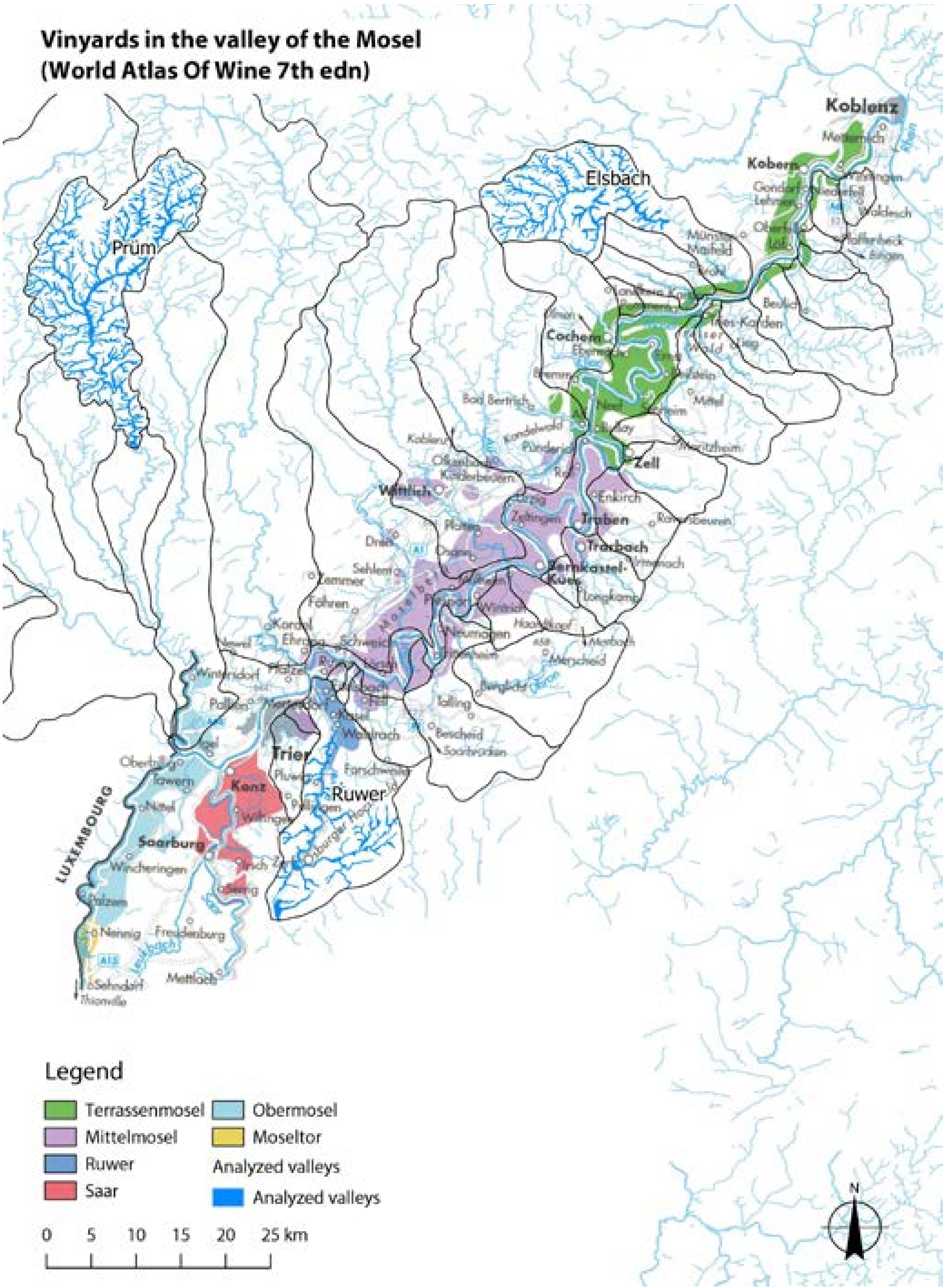

Figure 3. The location of vineyards related to the potential retention areas (the U-shaped valleys The latter are delineated in black, with Prüm, Ruwer and Elsbach highlighted because these sub-basins are studied in more detail in this report."

Foot of the slope

Not only the region, but also the exact location of the restored sponge function is key: for maximum effectiveness it should be done at the foot of a slope. Most precipitation falling on the plateaus and slopes will come down and will pass the foot of the slope before it enters the stream. Retention at the foot of the slope will therefore decrease the discharge speed of a much larger area: the plateau and slope above it. This underlying principle greatly increases the efficiency of this solution: if all drainpipes and ditches at the foot of a hill are removed, the runoff response of the entire slope will slow down.

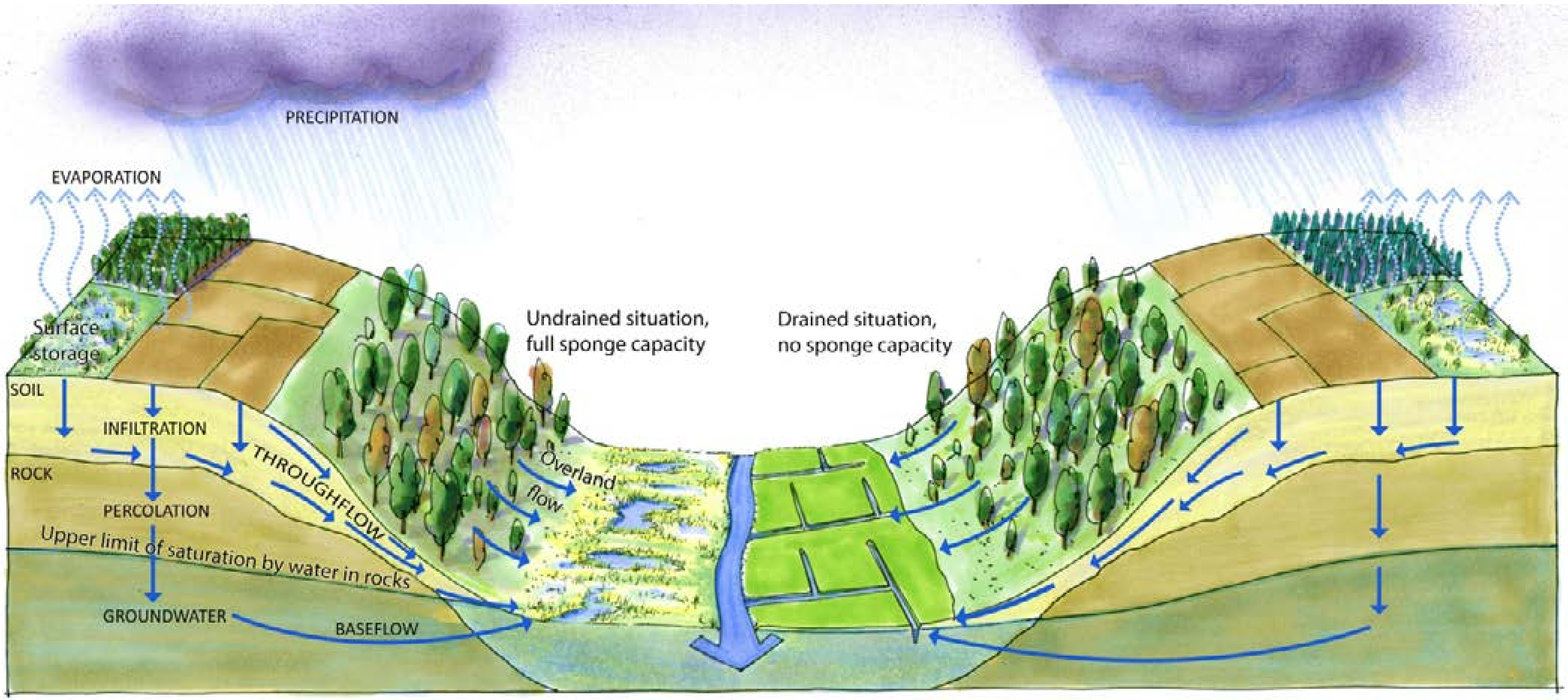

Figure 4. The role of drainage at the foot of the slope. On the right hand side, the valley is drained by means of channels, on the left hand side, the undrained situation.

Technically, restoration of ‘sponges’ is fairly simple: undoing drainage and trenching will enhance water retention in the soil. The rough marsh-vegetation developing on the (wet) surface, will even allow storage on the surface – shallow pools – because the hydraulical resistance of the vegetation will inhibit runoff. Figure 4 compares the current situation on the right, and the desirable situation of restored ‘sponge’ capacity on the left.

Integrated solution with multiple benefits
The line of reasoning behind the sponges approach is, that the peak flow to the main branch of a river can be reduced by retaining water for a longer period of time in the sub-basins. Chapter 1 in PART II deals with this in more detail. However, the range of potential benefits is broader: wetter soils offer a good starting point for restoring biodiversity: peatlands, marshland and wetlands. And there is potential for new business opportunities and jobs (chapter 2 in PART II). Natural retention therefore is an integrated solution in the toolbox of water managers.

Where do we stand?

*In 2004, WWF and Stroming published the vision ‘**Storing Water near the source’** in which the concept of natural sponges and their potential is analysed and described.*

*In 2013, WWF, Stroming and Carthago published **‘Possibilities for storage? Stores of possibilities!’** The experience of the years since publication of the vision in 2004 learned which concerns and doubts to the sponges approach were most often expressed. The publication ‘Possibilities for storage’ deals with them and elaborates counter arguments regarding many of the objections.*

*In 2014, Stroming did a **first scoping study of the costs and benefits** of the sponges approach. Stroming compared the sponges approach with the Room for the River programme in the Netherlands and did a quick scan of the costs involved to reach a similar decrease of discharge using the sponges approach. This project was funded by the Platform Biodiversiteit, Ecosystemen & Economie (Platform BEE) of the Dutch Ministry of Economic Affairs.*

*Since 2014, WWF Netherlands and Wetlands International have cooperated in activities with the aim to bring the sponges approach further. This has resulted in the present project, ‘**Restoration of the marshes in the valleys of the middle mountains of the Rhine basin for flood and drought risk reduction’**. This project was jointly funded by WWF Netherlands, Michael Otto Stiftung (granted to Wetlands International – European Association) and the European Life- NGO funding (also granted to Wetlands International – European Association). The results of this project are described in this report.*

All the above mentioned publications are available at www.stroming.nl

1. Retention potential: geomorphological and hydrological analysis

1.1 Selection of study area.

The buildup of floods in the Rhine river starts in the Middle Mountains in Germany: the hilly and mountainous areas where the tributaries of the Mosel, Main, Neckar, the Upper Rhine and numerous smaller tributaries originate (see figure 5.). Therefore this area was selected for this project/study.

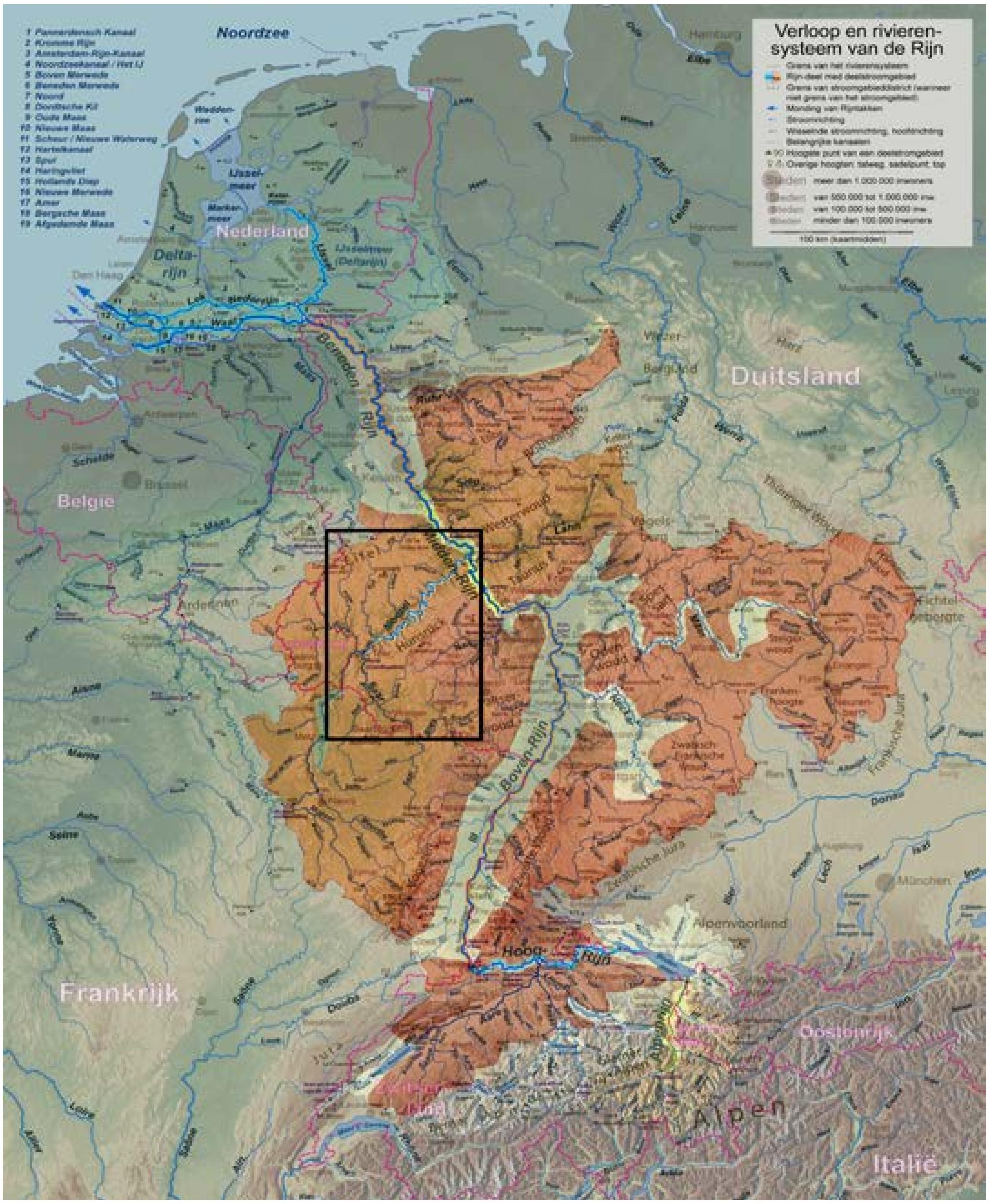

Figure 5. Tributary basins of the Rhine. Each tributary basin has several sub-basins (e.g. Mosel, Neckar). The box indicates Northern part of the Mosel basin.

The buildup of floods starts here because
- these areas receive a relatively large amount of rain, 50 to 100% more than the down-stream areas; (figure 2.)
- water is quickly transported downstream: the plateaus and slopes have little capacity to

retain water. Therefore the precipitation enters into streams relatively fast, especially in cases in which the floodplains of the streams are drained.

It is here where possibilities should be sought to slow down the runoff of water and create new possibilities for retention. Characteristic of these Middle Mountain regions are the broad U-shaped valley-floors in the upper and middle sections of the tributaries[11]. So, in principle, suitable areas for natural retention should be available here.

In order to test the validity of this assumption, the current study zoomed in on a representative area in het Middle Mountain region: the northern part of the Mosel catchment. This area was chosen on the basis of the following criteria:
- presence of characteristic, relatively flat valley floors
- tributaries which, during peak floods, discharge substantial volumes of water
- sufficient data (measuring stations) on discharges.

Figure 6. Map with several sub-basins (= enlargement of box in figure 5.) The box in this figure indicates the sub-basin of the Prüm, a tributary to the Mosel which in turn is an important tributary to the Rhine.

As a next step the area of flat valley floors was determined in 4 sub basins (figure 6.). Areas with slopes of less than 10% were identified as being “flat”. These areas are, from a geomorphological point of view, suitable for creation of natural retention and cover between 6-8% of the area of the total sub basin.

1.2. Hydrological effectiveness within study area

In order to determine the potential effect of natural storage in the study area, a hydrolog-

11 The lower sections are often V-shaped valleys where space for natural storage cannot be found (Storing Water Near the Source, 2004).

ical travel time analysis was made. The parameter for hydrological travel time allocated to “natural sponges” was 2 times higher than the parameter for “non-sponges” in other words: the assumption was made that water travels through a natural retention area at a pace that is 2 times lower[12] than in areas which are under unchanged (mainly agricultural) management. The results are shown in figure 8: if all the yellow and green parts in figure 7 are developed as natural sponges, 5-8% of the run-off of the basin will be sufficiently retained to prevent it from contributing to the peak. This corresponds with a 5-8% lower peak level than without natural retention.

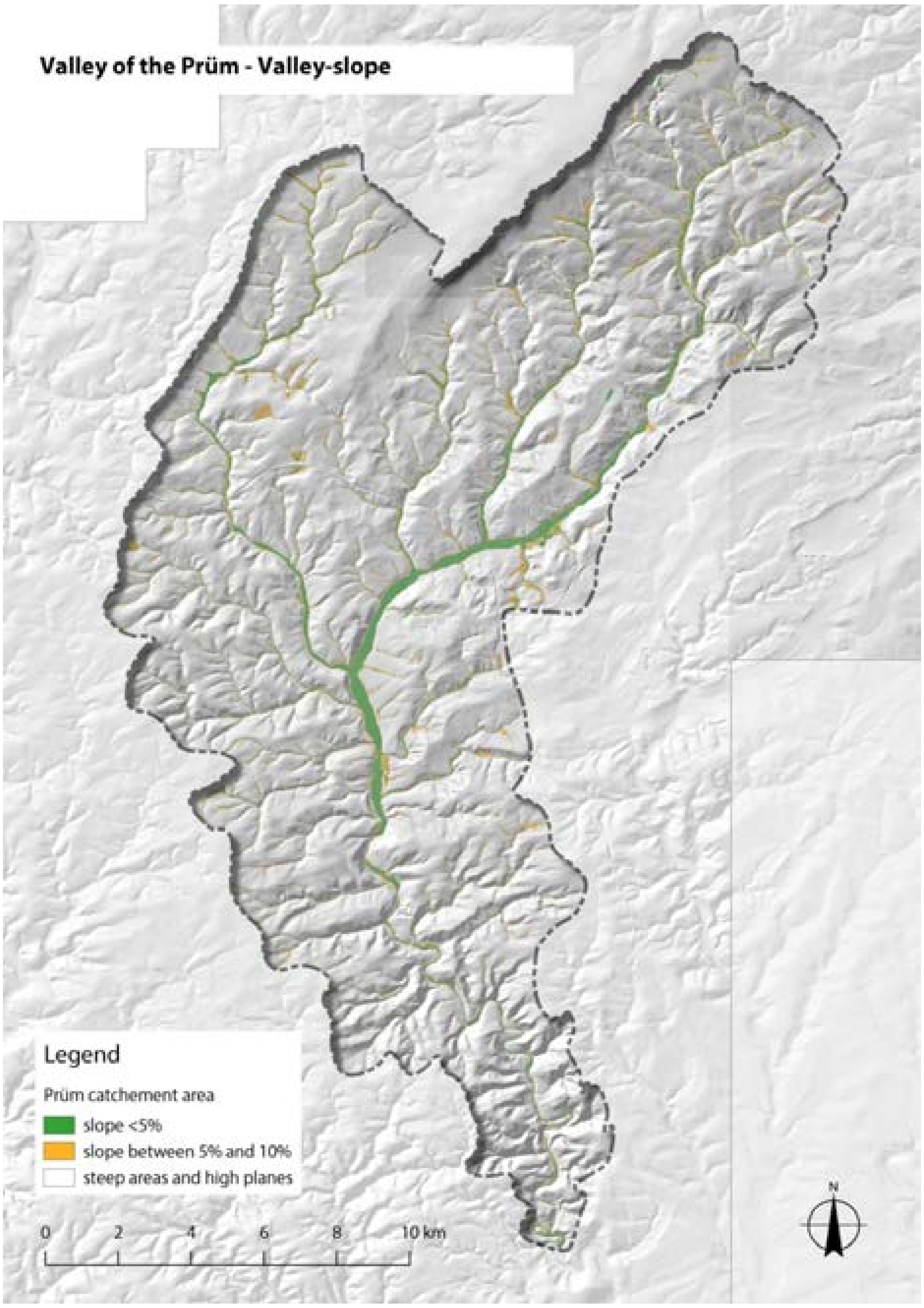

Figure 7. Result of GIS analysis of the Prüm valley. The green (slope <5%) and yellow (slope between 5% and 10%) areas are suitable, from a geomorphological point of view, for natural storage.

The GIS analysis provides a very precise indication of the surface area of suitable valley

12 According to the Manning formula the velocity of water flow is inversely proportional to the Manning coefficient. The range of 2 used in the analysis covers the majority of variations in land use. This is explained in more detail in the box ‘Calculating retention potential by travel time analysis’ in annex 1.

floor, but it takes a lot of time calculate het potential for natural retention through this method. Therefore, a simplified method was used to identify the suitable areas (the so-called Geomorphologic analysis). The outcome of this simpler method proved to give a very good match with the GIS analysis and therefore could be considered to be reliable input for the calculations.

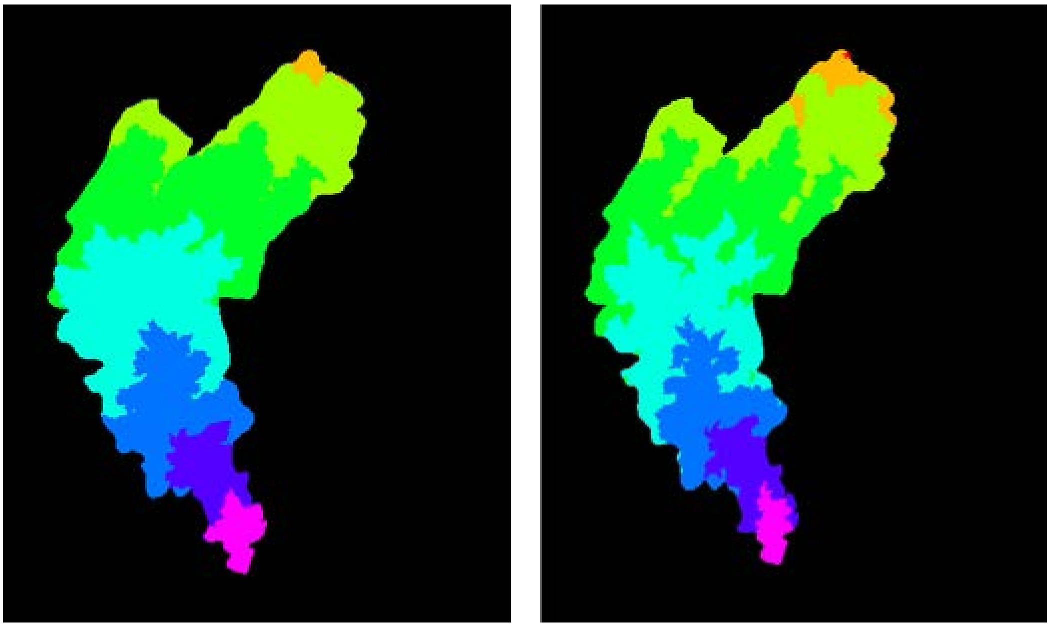

Figure 8. Total travel time from water from an individual location to the outlet of the Prüm basin (which is located in the southern part. Left is the situation with the artificial drainage still in place and right is the situation in which artificial drainage is removed and the local travel time is increased. The area with large travel times (coloured orange and light green in the figure) becomes larger, the area with a short travel time (pink) becomes smaller.

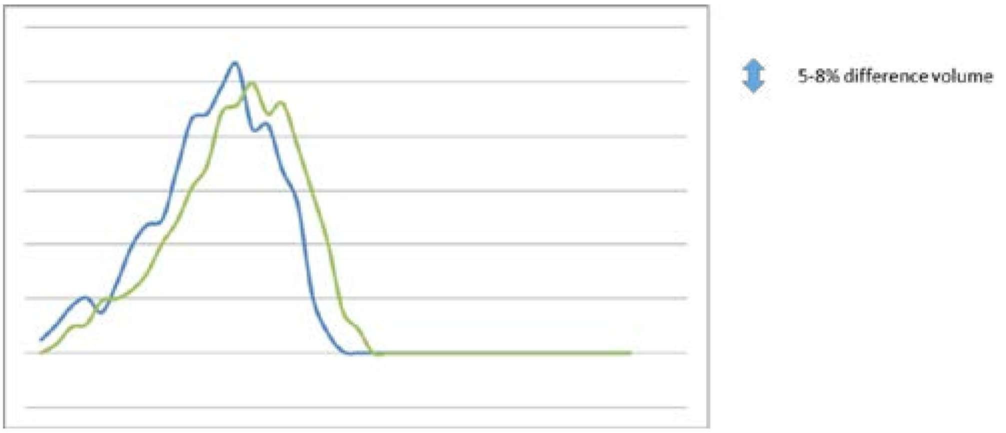

Figure 9. Synthetic hydrograph based on the time travel concept, for the situation with and without sponge restoration in the Prüm catchment. Blue = situation without sponge restoration, green = situation with sponge restoration. Y-axis = discharge X-axis = time. Development of sponges would lead to 5-8% lower peak discharges.

1.3. Perspective

The results from the current study at least provide partial evidence for the hypothesis that natural retention can result in substantial reduction of flood peaks, also on regional or basin scale. Calculations were repeated for a number of other Mosel sub-basins. The results achieved were similar to that of the Prüm. (see Annex 1). Although it is not certain that similar results will be achieved for (sub-basins of) all the other tributaries to the Middle Rhine (Neckar etc.), there is as yet no reason to assume that these would be very different.

2. Other Potential Benefits

The positive effects of restoring sponges in middle mountains are not limited to flood risk mitigation. Besides an impact on reducing floods and droughts, outcomes of this measure will include more room for nature, enlarged recreation values, carbon sequestration, and reduction of nutrient runoff from agricultural fields. In other words, it will deliver socioeconomic co-benefits for biodiversity and society.

On the policy level, rewetting floodplain marshes is a measure which contributes to the integration of sectoral policies (water, nature, safety, agriculture, climate) by improving water quality and in compliance with objectives of the Common Agricultural Policy (CAP) and Water Framework Directive. It could potentially be a solution which contributes to the current greening transition of the CAP. We observe European momentum has been reached to truly enhance policy integration. The European Commission invests in demonstrators of nature-based approaches to address some of the aforementioned uncertainties, for example through its Horizon2020 2016-2017 work programme[13], the establishment of the Natural Capital Financial Facility[14], the development of Trans-European Network for Green Infrastructure[15] to halt the loss of biodiversity, and the current public debate on reform of the CAP.

Some of the benefits can be translated into specific values. We should differentiate between:

a) benefits that can be included in budgets of projects (i.e. there is someone willing to pay at the project level)
b) societal benefits which can be used in lobby and communication, but cannot be included in budgets at the project level

Both of these benefits are typically included in a cost benefit analysis. However concrete benefits can only be calculated when applied to a concrete area. For this report only the second kind of benefits can be described in general terms.

2.1 Water quality and biodiversity

EU-legislation such as the Water Framework Directive (WFD) is a key driver for improving **water quality**. Regional, national and EU-funds are spent on reducing ground- and surface water pollution and on hydromorphological changes aimed at improving the ecological water quality. Introducing water services (such as sponge restoration) as a business model for farmers and thus extensifying the agricultural production will lead to improved water quality by:

a) improving the hydromorphological situation: by restoring floodplains and wetlands along the banks of streams the base flow of streams will be improved, it will bring back wet habitats along streams and rivers and it helps aquatic species that spend part of their life cycle on (wet) land. Hydromorphological improvements have proven to be crucial for achieving the (ecological) quality standards under the WFD.

b) decreasing runoff of nutrients and other pollutants into the water. Extensifying agriculture along the stream will help improving water quality, as 60-100% of surface water bodies in Germany and the Netherlands are affected by pollution from agriculture.

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13 The EC Horizon 2020 Work Programme 2016 – 2017, part 12. Climate action, environment, resource efficiency and raw materials, topic Nature-based solutions for territorial resilience, recognizes the lack of 'robust EU-wide evidence of the cost-effectiveness and longer-term social, economic, cultural and ecological benefits of these solutions'. 'The objective [...] is to position Europe as world leader in innovation through nature based solutions [..] to simultaneously improve economic, social and environmental resilience of rural and natural areas by taking into account the wider system and aiming at ecological stability.' http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-climate_en.pdf

14 The main aim of the NCFF is to demonstrate that natural capital projects can generate revenues or save costs, whilst delivering on biodiversity and climate adaptation objectives. http://ec.europa.eu/environment/life/funding/financial_instruments/ncff.htm

15 'Developing a Trans-European Network for Green Infrastructure (TEN-G) would have significant benefits for securing the resilience and vitality of some of Europe's most iconic ecosystems, with consequential social and economic benefits.' http://eur-lex.europa.eu/resource.html?uri=cellar:d41348f2-01d5-4abe-b817-4c73e6f1b2df.0014.03/DOC_1&format=PDF

Improving the hydromorphological situation, the base flow of streams and improving water quality will also result in more **biodiversity**. Extensifying agricultural production will also provide better opportunities for a more diverse flora and fauna and thus improving biodiversity.

2.2 Drought management

The potential for diminishing drought is limited when using this approach only. As the travel times decrease, the flood peak is lower but lasts longer. The water will be stored in the soil and the discharge will be spread out over a longer period of time. This buffers water and will **decrease periods of drought**. However, these methods of decreasing flow velocity for lower and longer flood durations are typically associated with a short time span. Decreasing flood velocities and delaying time to peak flow with several hours or days can have a significant effect on the peak flow. For drought reduction, this delay in timing is insignificant. In order to have an impact on drought situations, water should be retained for weeks and months - much longer timescales than the timescale we are looking at with floods. The volumes of water needed to alleviate drought situations is much larger than the volumes stored for peak flow reduction. In order to start buffering significant amounts of water for drought reduction, infiltration on the plateaus (and not so much in the river valleys) is a much more promising approach.

2.3 A new business model for farmers and greening of the CAP

Introducing sponge restoration as a water service for integrated water management and as such compensate landowners for changing or extensifying the agricultural production can provide **a new business model for farmers** in (wet) areas where agricultural production is now marginal. This perfectly fits into a greening transition of the **Common Agricultural Policy (CAP)**. Under the present policy, it is possible for farmers to receive direct payments if they dedicate 5% of their lands (e.g. the areas along streams which are most effective as a sponge) to 'ecologically beneficial elements', such as protecting water or conserving soil carbon. Apart from these European funding arrangements, additional (local, regional, or national) programmes exist, like the Naheprogram in Rheinland-Pfalz in which sustainable farming practices were supported. Adding funding from water management budgets to this purpose can make water services a powerful tool for integrated and nature-based water management.

2.4 Carbon sequestration

This case study has showed that the potential for carbon capture by natural sponges is present but modest. An example calculation has been carried out for the Prüm catchment. Land use change from intensive to extensive agricultural production can lead to a capture of 595 tonnes of CO_2 equivalents (total for Prüm basin). For a period of 20 years this amounts to 11,906 tonnes of CO_2 equivalents. If the same amount of land would be converted into forest, the climate impact for a period of 20 years would be 331,929 tonnes of CO_2 equivalents. Therefore land use changes in the Middle Mountain region will most likely not provide opportunities for selling carbon credits as a business model. Due to the absence of peat bottoms or soils with a high organic content in the study area, the effect of avoided oxidation emissions is hardly present. This greatly limits the climate impact. However the restoration of sponges does modestly contribute to CO_2 reduction aims. Detailed information about the calculations can be found in annex 2.

2.5 Potential other socio-economic benefits

Natural beauty can deliver socio-economic benefits like an increase in expenditures related to recreation and tourism and increased housing prices which can lead to higher tax income. The source of the information in this paragraph is a report by Stroming: 'Possibilities to save money by making use of nature', commissioned by the Coalition Natural Climate

Buffers.

An international study (TEEB), has ranked income from tourism and recreation (Russi et al, 2013). The numbers were based on multiple studies. For rivers, lakes and marshes, the potential for toursim varies betweens €5 and €3,000 per hectare per year.

A study of Bureau Ruimte en Vrije Tijd in the Netherlands (Space and Leisure Office, 2012) compares three redeveloped areas along the river. It shows that the most profitable area (170 jobs and €6.3 million expenditures per year) had the richest nature and was the most accessible to the public. Expenditures and employment were more than twice as high when compared to agricultural area and in an area with limited access fort the public. The rich nature had developed despite the presence of people. The research underlines that in robust, high-dynamic wet nature recreation and nature go well together.

Housing prices

A house in attractive surroundings is more expensive than the same house in a less attractive area. A beautiful environment thus adds value to a house. Kroll and Cray (2010) state that the value of a house is 5-10% higher when it has nearby trees or an attractive landscape based in the surroundings, based on an international literature study. Increase of value was particularly linked to houses with a direct view on the attractive landscape. Nearby water was also found to have a positive effect on prices although the results here were less clear.

This idea has been confirmed in several studies based on the Dutch housing situation.

Bade and Van der Schroeff (2006) have researched the added value of nature tot housing prices on the Veluwe in the Netherlands. They assume an additional value of 10-20% and conclude that the total added value of nature on real estate results in € 4.1 billion of additional tax income for local municipalities. Also, Bervaes and Vreke (2004) find significantly higher housing prices in natural surroundings. This study specifically looked at houses adjacent to water or green spaces. Water at the back of a house adds a value of 15% to the house and an open landscape adds 12%. Water at the front of a house results in a value increase of about 6%. Brouwer et al (2007) conducted research into the relationship between housing prices, water types and water quality. Strikingly, the additional price of water near houses is by far the largest in urban areas (3.6-5.8%). For all other waters examined, the additional price is limited to 0.1-0.8%. Visser and Van Dam (2006) also conclude that a green and blue environment increases the value of a house on the basis of a broad literature study. Their conclusion is that the added value is 6-12%. In particular, a wooded area has a positive effect, with an additional value of €119 - €131 per m^2. Witteveen + Bos (2011) consultants, conclude that a view on green spaces, increases the value of a house with 5-14%.

All in all we can say that if sponge restoration adds to natural beauty, it can also deliver socio-economic benefits like an increase in touristic expenditures and increased housing prices. Probably this effect will be larger if sponge restoration leads to land use change from agriculture to nature instead of only changing the produce from conventional to wet agriculture.

2.6 Policy level

On the policy level, rewetting floodplains is a measure which can contribute to the integration of sectoral policies (water, nature, safety, agriculture, climate, spatial planning) by improving water quality and in compliance with objectives of the Common Agricultural Policy (CAP) and Water Framework Directive. It could potentially be a solution contributing to the greening transition of the CAP. We observe European momentum has been reached to truly enhance policy integration. The European Commission is investing in demonstrators of nature-based approaches to address some of their uncertainties, for example through its Horizon2020 2016-2017 work programme[16], the establishment of the Natural Capital Financial Facility[17], the development of EU-level Green Infrastructure to halt the loss of biodiversity, and the current public debate on the reform of the CAP.

16 The EC Horizon 2020 Work Programme 2016 – 2017, part 12. Climate action, environment, resource efficiency and raw materials, topic Nature-based solutions for territorial resilience, recognizes the lack of 'robust EU-wide evidence of the cost-effectiveness and longer-term social, economic, cultural and ecological benefits of these solutions'. 'The objective […] is to position Europe as world leader in innovation through nature based solutions [..] to simultaneously improve economic, social and environmental resilience of rural and natural areas by taking into account the wider system and aiming at ecological stability.' http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-climate_en.pdf

17 The main aim of the NCFF is to demonstrate that natural capital projects can generate revenues or save costs, whilst delivering on biodiversity and climate adaptation objectives. http://ec.europa.eu/environment/life/funding/financial_instruments/ncff.htm

3. Costs

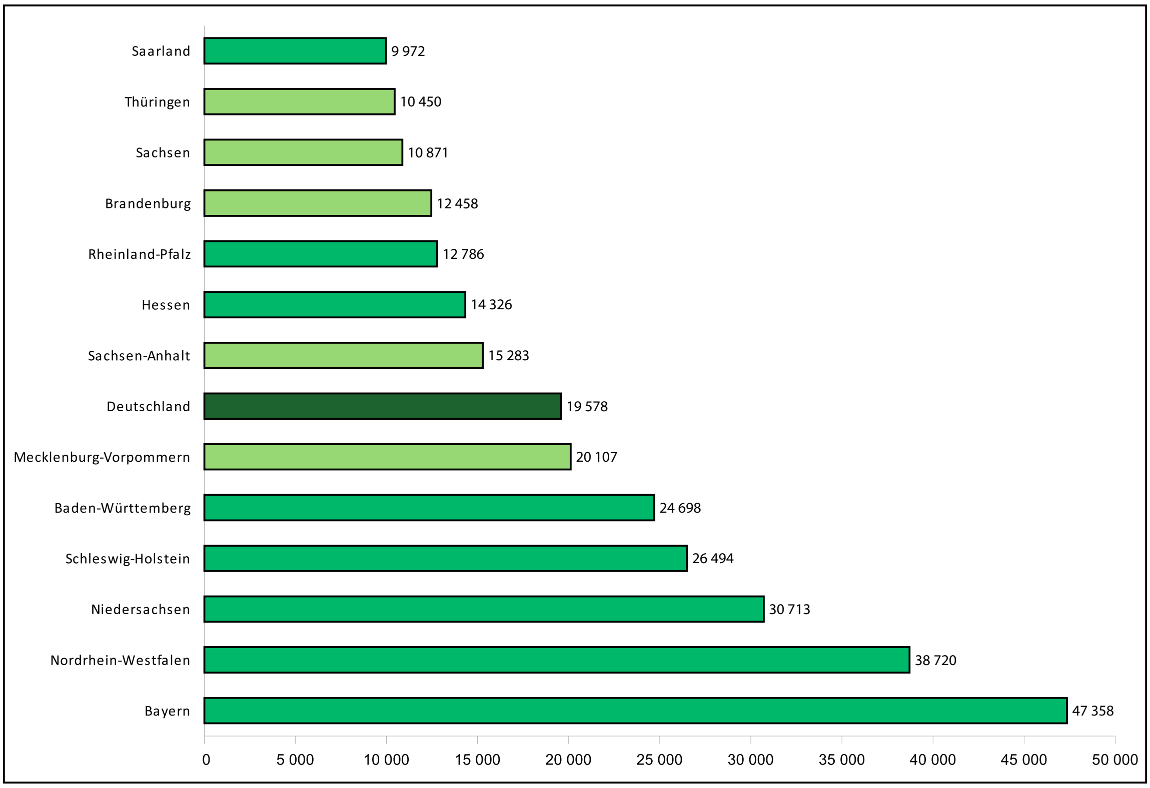
The sponges approach requires the restoration of natural drainage conditions. As a consequence the agricultural production of the fields affected will decrease, and this constitutes the largest cost component of the intervention.

The only way to convince landowners to cooperate is to make it affordable and profitable for them to do so. Overall, there are 3 options to realize this.

1. Obtain ownership of the land
2. One time compensation
3. Management agreement with the owner

3.1 Obtain ownership

Durchschnittlicher Kaufwert je Hektar veräusserter FdlN in den Ländern im Jahr 2015



Obtaining ownership of suitable lands obviously is the most expensive option. In Rheinland-Pfalz the average price for agricultural land in 2015 was almost €13,000/hectare. That was well under the German average of around €19,500 per hectare. And certainly much lower than prices of agricultural land in the Netherlands. In 2012, average prices in the Netherlands were almost three times as high as average prices in Germany (in the Netherlands, almost € 50,000/hectare, in Germany around €17,000/hectare).

For example, buying potentially suitable land in the valley of the Prüm (1701 hectare, the example used in the CO_2 capture calculation in annex 2) would require an investment of almost €22 million based on these averages.

3.2 One time compensation

The second option is to compensate the landowner for the use of his land. The most common way to do that- and which fits within the EU regulations regarding State Aid - is to compensate the land owner for the decrease in land value from agricultural land value to natural land value. More concrete information on this issue can only be obtained with a specific area/ landowner in mind.

3.3 Management agreement

The third option is to compensate the landowner for loss of income. Such a management contract needs to comply with EU regulations on State Aid which means that the payment must be based on real loss of income, including compensation for direct or administrative costs related to the contract. Such an agreement would also include a specific description of what activities the owner can and can't do on his land and how this influences the income position of the landowner. Obviously, this option would mean more administrative pressure for the landowner than the 2 options described above. Another disadvantage is, that the continuity of this option is less secure. The advantage is, that the costs for the water management will be spread out over a longer period of time. More concrete information on this issue can only be obtained with a specific area/land owner in mind.

4. Stakeholder analysis and Stakeholder engagement

4.1 Acceptance of nature based solutions in general

Policy-makers and water managers increasingly understand there is a need to work with nature, not against it. There is a need to bring back a robust system based on natural processes. Although decision makers at EU and national level have adopted policies which stimulate integrated, nature-based solutions in water management, implementation of these measures is often lagging behind. Flood management models based on traditional hard engineered solutions remain dominant, at expense of the wider benefits being delivered to society by innovative, nature-based approaches.

Social acceptance to nature-based solutions is also not a given; it requires knowledge and understanding of how to explain innovative restoration approaches that often seem the opposite of accepted flood defense approaches, and making the true costs and benefits of different river management and related development scenarios transparent to allow restoration solutions to be seen as viable, for financing and investments.

4.2 Obstacles to implementation

Despite European Water Directives and national regulations (such as the Federal Water Act in Germany) that guide European states to avoid deterioration of their rivers and related nature and to capitalize on the natural values and benefits provided by them, there is a (governance) impasse in large scale implementation of naturalization measures or a systems approach[18]. Even with agreement on the principles of nature-based solutions, awareness is still low. Flood risk management authorities want to understand the procedural, organizational and institutional barriers to nature-based solutions. There is a lack of empirical data on the performance of these measures. Moreover, the greater uptake of nature-based approaches is prevented by a lack of understanding of impacts and benefits of upstream land use management, integration of land use planning and flood risk management, as well as experience with downstream funding of upstream measures.

Indeed it should also be acknowledged that this approach will deteriorate circumstances from a conventional agricultural perspective. Innovative solutions like wet agriculture or a compensation facility (a water-services-system) will need to be developed in cooperation with the agricultural sector.

The UNECE Water Convention, which has been ratified by all the riparian States of the Rhine, aims to improve transboundary cooperation in river basins. The Netherlands and Germany are both active members. By ratifying this Convention, countries underline the importance of the basin approach. This means, that these countries have committed themselves to taking into account the whole basin when they decide about the location of measures to improve river management. In theory, this would mean that the Netherlands could also invest in measures in Germany if these would be more effective or efficient. In practice, this is not reality yet. Despite the excellent cooperation in the International Commission for Protection of the Rhine (ICPR) all riparian states take their own measures. For example, the Dutch Delta programme only covers the Dutch part of the river basin. Informally, government agencies and water professionals admit that this approach is sub-optimal, that more transboundary cooperation would be needed in the future, to be able to adapt to climate change.

The challenge is to meet many preconditions relating to political and social awareness, financing, knowledge base and technical justification.

18 Voulvoulis e.a. (2016) recognize the absence of a paradigm shift towards the systems (integrated) thinking in water policy implementation, despite this being the core principle of the EU Water Framework Directive. http://dx.doi.org/10.1016/j.scitotenv.2016.09.228

4.3 Most important stakeholder related hurdles and chances

Development of natural storage requires the support and cooperation of a wide array of stakeholders. Therefore a stakeholder analysis was carried out, involving interviews with 32 individuals, representing a total of 30 German organisations and institutions on national, regional and local level. Contact with Dutch stakeholders has been an ongoing process in the past years and has, among other things, resulted in Parliament requesting the Minister of Infrastructure and Watermanagement ".. to investigate the effectiveness of natural retention in the source areas of the Rhine in the Middle Mountains in Germany and inform Parliament about this"[19]. During this stakeholder analysis the focus was on stakeholders in the Mosel basin. The main goal was to gather information about current water resource management projects and practices in the Mosel basin by determining the opinions of various German stakeholders regarding water retention areas, wetlands restoration and land use within the basin.

Interviews took place in 2 rounds. In the first round 23 persons were interviewed, representing 23 institutions in the fields of water management, agriculture, nature conservation and science from seven counties within the Mosel basin. Over a period of two months telephone interviews have been conducted. As became clear during the interviews most of them had limited or no direct involvement in natural storage projects. Therefore a second round of interviews was done with 9 persons representing 7 organisations having such direct involvement.

Results (1st round of interviews)

Opportunities related to natural storage are seen in the fields of:

- Local community-building
- Local and regional flood prevention
- Recreation
- Biodiversity and nature conservation
- Connection to existing projects

Especially stakeholders from the local community's water sector see the natural storage approach as an opportunity. It is easier and faster to implement actions on a small-scale level compared to the whole basin. Municipalities foster re-naturation measures in order to prevent flooding with positive side effects of strengthening biodiversity and recreation. All together the interview partners think that local measures would also improve the community mind set. The local stakeholders encouraged the Sponges approach to integrate in already running projects (such as AktionBlauPlus) or re-start older, successful initiatives.

Concerns and constraints expressed can be summarized as follows:

- The surface area available for natural storage is limited (much is taken up by cities, roads, agriculture)
- Effect on the basin-wide discharge
- Land is expensive/valuable
- Benefits on a river-basin scale (e.g. flood prevention in Koblenz or Nijmegen) will not motivate local authorities and land-owners (e.g. in the Mosel basin) to offer land for natural storage.

The ministries on state level argued that the floodplains would be too small. Because of this, natural storage will possibly/probably/certainly not be effective on (inter)national scale and large (100 year) floods. Representatives from the International Commission for the Protection of the Mosel and the Saar (IKSMS) argued that there would be no effect on the overall Rhine-water discharge during flooding even if all existent technical storages

19 Motion 7 July 2016 by 2 members of Parliament: Koser Kaya and Belhaj: Motie van de leden Koser Kaya en Belhaj over onderzoek naar de effectiviteit van natuurlijke retentie in de brongebieden van de Rijn: https://www.tweedekamer.nl/kamerstukken/detail?id=2016Z14463&did=2016D29511

('Polder') in the Mosel basin (as well as in the Saar basin) would be used for water retention. According to IKSMS, both technical and natural measures do not contribute to flood protection in the overall Rhine basin, but can reduce the local and regional flood risks at the most. Besides, the Mosel basin's valley structure is mainly v-shaped and has not a lot of flat areas for potential retention areas (u-shaped valley required). The stakeholders also mentioned that measures in the Mosel basin would be negligible and have no effects to the Rhine during big flooding. Land owners at the tributaries (mostly farmers) are mostly not willing to sell their properties due to old family rights and increasing values for land in the region (e.g. vineyards). Additionally, local stakeholders rather prefer to think on local level instead of having river-wide concerns. The Netherlands is too far away and downstream issues do often not bother the locals. A more detailed overview of all approached stakeholders can be found in annex 3.

Results (2nd round of interviews)

Interviews with district and municipal administrations actively involved in current or former natural storage projects turned out to generate more support for the sponges approach. Several stakeholders can imagine project co-operations within the Mosel basin based on the Sponge-approach. A research for relatable natural water retention projects (mostly former or current "AktionBlau"/AktionBlauPlus" initiatives) and direct contacts to the responsible project managers led to a more positive feedback. When it comes to potential pilot areas (promising on the basis of both physical conditions and local interest) the following locations/regions were mentioned:

- Holzbach
- Ruwer
- Obere Ruhr
- Kyll
- Olewiger Bach
- Konzer Bach
- Simmerbach
- Appelbach

Depending on future projects and the correct basic requirements for natural retention (e.g. slope elevation), these areas could be potential pilot regions for the implementation of the sponge approach. For example, a relevant project at the river Kyll (a tributary to the left of the Mosel) has been conducted between 2008 and 2012 by NABU and the University of Trier focusing on the redesign of the estuary by reconnecting abandoned channels, pre-structuring flood channels and synclines, as well as planting alluvial forest. It was categorized as highly relevant for the sponge approach because of the rivers location in the low mountain ranges of Rhineland-Palatinate, its water wealth and the integrative approach combining different ecological measures. A more detailed overview of all relevant AktionBlauPlus Projects and relevant actors can be found in annex 3.

Overall conclusions

In general, parties active at the local or regional level emphasise the opportunities and are interested to further explore possibilities for natural storage; parties active at the national level put more emphasis on the concerns they have, and therefore willingness to participate in next steps is limited or absent. Another observation is that people with more direct involvement in natural storage put more emphasis on the possibilities, people with less involvement emphasise the constraints[20].

20 Although a comparison with the Dutch situation was not part of the stakeholder analysis, experience shows that this mirrors the situation in the Netherlands. Local water management authorities in the Netherlands are quite active in projects for water storage and apparently see benefits in this; national water management authorities much less so.

Implications & perspectives

It could be argued that the concerns and constraints expressed during the interviews reflect a lack of knowledge or understanding. Technical storage measures (e.g. polder) have always been favoured over natural storage in the past in Germany. Studies of negative effects of polder on the ecosystem in recent times have led to a more natural approach which, however, has not reached all stakeholders in Germany yet. In our view the constraints expressed should neither be ignored, nor be seen as a reason to refrain from next steps. They should rather be translated in guidance for future steps. Therefore it could be useful for future projects to organise information campaigns along German rivers in cooperation with German and Dutch water professionals in order to resolve certain knowledge gaps.

After all, there is broad agreement that natural storage brings multiple benefits, at least at local or regional level. Doubts and concerns only begin when the hypothesis that natural storage can have a meaningful impact on (inter)national level is introduced.

On the basis of the stakeholder analysis the following critical success factors can be identified:

1. Natural storage should be developed on locations suitable to store relatively large quantities of water in/on a relatively small surface area. This is necessary because space is limited. This is true for any new spatial initiative and thus also – and perhaps in particular – for natural storage.

2. The benefits on a local scale must be clear and tangible – either "in kind" (e.g. less local flooding) or financial (more income from tourists). They should be clear for the land-owner as well as for the authorities whose support or cooperation is needed.

3. Benefits on a national or international level (e.g. flood prevention in Koblenz or Nijmegen) should be translated into benefits on a local level in order to obtain or enhance local cooperation. In concrete terms: they should be translated in monetary terms (e.g. compensation fees), new opportunities for local businesses (e.g. new export opportunities for local produce) etc.

4. The lack of acceptance of natural storage is directly linked to the lack of knowledge. In order to gather more support– on all administration levels –stakeholders require more clarification regarding location and scale of implementation as well as the expected effects of the measure.

5. Literature

The stakeholder analysis is accompanied by a review regarding available literature focusing on hydrological models, storage and flow properties. The results were put together, systematically analysed and reviewed on its relevance for the Mosel Basin. The literature analysis main focus lies on:

- Hydrological processes in storage bodies
- Flood modelling
- Effectiveness of natural retention

Although the authors come to varying conclusions, there are several aspects that they have in common. First of all, most relevant projects mentioned in the literature successfully implemented local flood prevention measures. The measures are considered effective and useful for the protection of small-scale risk regions and the mitigation of small flood events. However, the volume that can be held back by local measures is evaluated to be not sufficient enough for a significant effect on the superordinate river system. This assumption goes along with the statement of several interview partners in the stakeholder analysis. In addition, the positive effect is said to vanish as soon as quick and high flooding, such as 100year flood events, appear. One of the authors considers tributaries irrelevant for flood protection in general.

With regard to the concrete types of measures, dyke relocations for recovery of flood plains are assessed the most effective. Although the same difficulty applies to this measure, an important additional benefit appears with the renaturation of meadows: the improvement of biodiversity in the respective area. In the basin areas of the rivers Rhine, Mosel and Saar it is stated that not enough potential flood areas are available to have an impact on flood prevention – a statement which has also been mentioned by several stakeholders in Germany.

One author suggests taking on-site measures in the Netherlands in order to solve the issue of flooding. Other statements say that large-scale projects need to be commenced for greater impacts on flood protection on a basin-wide approach. Therefore, major challenges such as the coordination across regional and disciplinary boundaries have to be met in the future.

A more detailed literature analysis with the respective literature and authors can be found in the annex.

6. Recommendations and long term vision

6.1 Recommendations for follow up

I. For the near future, it will be easier to find support for this approach if we shift our focus to local impacts such as local flood protection, business opportunities, river and nature restoration and community projects. For implementation of local pilot projects this will be more effective than focusing on the whole basin and the impacts to be achieved in the Netherlands.

II. At the same time, we think that the potential effects on the basin should not be lost out of sight. This can be an important added value of our approach, especially from the perspective of international organizations like WWF and WI-EA. These effects need to be further researched and substantiated.

III. Other models of land management (like water services and compensation) should be further explored for this purpose. Buying all the land needed for this approach is not realistic and not necessary as large amounts of surface area would be needed. Alternative models of land management can provide a new business model for farmers and yield lower costs. This needs to be explored further.

IV. Find an ally in the agricultural sector. A total change of land use is not needed and probably not realistic. Taking out the drainage and changing agricultural use along streams in upstream regions can provide new business opportunities for land owners if they get paid as service providers for water management. Introducing water services as a new business model will appeal to some farmers and will fit into the development towards more sustainable agriculture.

V. Supporters of the sponges approach can be found among water managers that embrace integrated water management and nature-based solutions. Cooperation with these people and organizations is needed to make the beneficial impacts more tangible and concrete. This will also help to convince the critics in a later stage. Several projects in Rheinland-Pfalz (the focus of our research) were identified which provide opportunities for cooperation, as we share the same ambitions. A pilot scheme could fulfil the request to deliver proof of hypothesis of a locally implemented measure, but securing support and resources for a pilot is a challenge in itself without the proof.

VI. Supporters of the sponges approach should also work together in additional lobby and communication about the need for the sponges approach and nature-based solutions in general. Mission work is still needed as social acceptance to nature-based solutions is not yet a given. This should be seen as a necessary transition in water management in order to tackle the uncertainty of climate change related precipitation developments.

VII. The sponges approach is a complex concept that can be easily misunderstood. To avoid resistance based on misunderstanding, all crucial aspects of the approach need to be constantly and thoroughly explained to and discussed with stakeholders.

VIII. There seems to be a discrepancy between the perception of stakeholders about the availability of spacious (u-shaped valleys) and what we have found in the analysis. Many stakeholders seem to think that there are no spacious (u shaped) valleys for restoration areas. They claim that there are just very few flat plains for potential retention areas; the rest is v-shaped. However, the method described in this report confirms the assumption that in the middle mountain region in Germany **we find many U-shaped valleys** which are potentially suitable for the sponges approach. This discrepancy should be seen as a matter of perception and as a difference in definition of how much space is actually needed in the vally. Opinions, interest and (professional) background very much influence the attitude towards the sponges approach. The results of the present analysis should be used to support future dialogue with stakeholders.

6.2 Our Long Term Vision

Our aim is to achieve a transition towards nature-based water management: basin wide implementation of nature-based solutions, of which the sponges approach is one of many measures in a nature-based toolkit.

We aim to test the concrete effects of the sponges approach on the ground, either in a project initiated by our consortium or by linking our ideas to other initiatives. The effects on water management and additional societal aims on a local and regional level have to be substantiated and monitored.

The effects of the sponges approach at basin level need to be convincing enough to add up to the list of reasons to implement the use of sponges in the whole river basin.

The above should ideally result in a water services market which makes it worthwhile for landowners to make their land available for this purpose and become involved in water management. Ideally, Germany and the Netherlands (and possibly also other riparian states) would also jointly create a transboundary funding mechanism for nature-based measures that are beneficial to both upstream and downstream users.

Annex 1. Technical analysis

PART I

GENERAL

In order to calculate the potential for storage, a four step approach was followed.

Step 1 Middle Mountains.

Which parts of the Rhine basin offer the best potential for natural retention? The answer: the Middle Mountains because this is where the floods built up. The reason behind this is that the Middle Mountains
- receive relatively large amounts of precipitation and
- the water here quickly runs downhill.

So it is here where we should look for possibilities to create extra space for natural retention (which can be added to the capacity which already exists). Characteristic of the valleys in the Middle Mountains are the broad valleys ("U-shaped") in the upper- and middle sections of the Rhine's tributaries. If artificial drainage there is undone, the natural storage capacity will be increased.

Step 2 Mosel basin, northern part

In order to test the hypothesis above, we zoom in on a representative area of the Middle-Mountains and investigate whether U-shaped valleys suitable for natural retention do indeed exist. Decided was to focus on the Northen part of the Mosel basin because:
- presence of characteristic U-shaped valleys
- presence of streams with substantial peak discharges
- presence of measuring stations and hence data on discharges in the current situation.

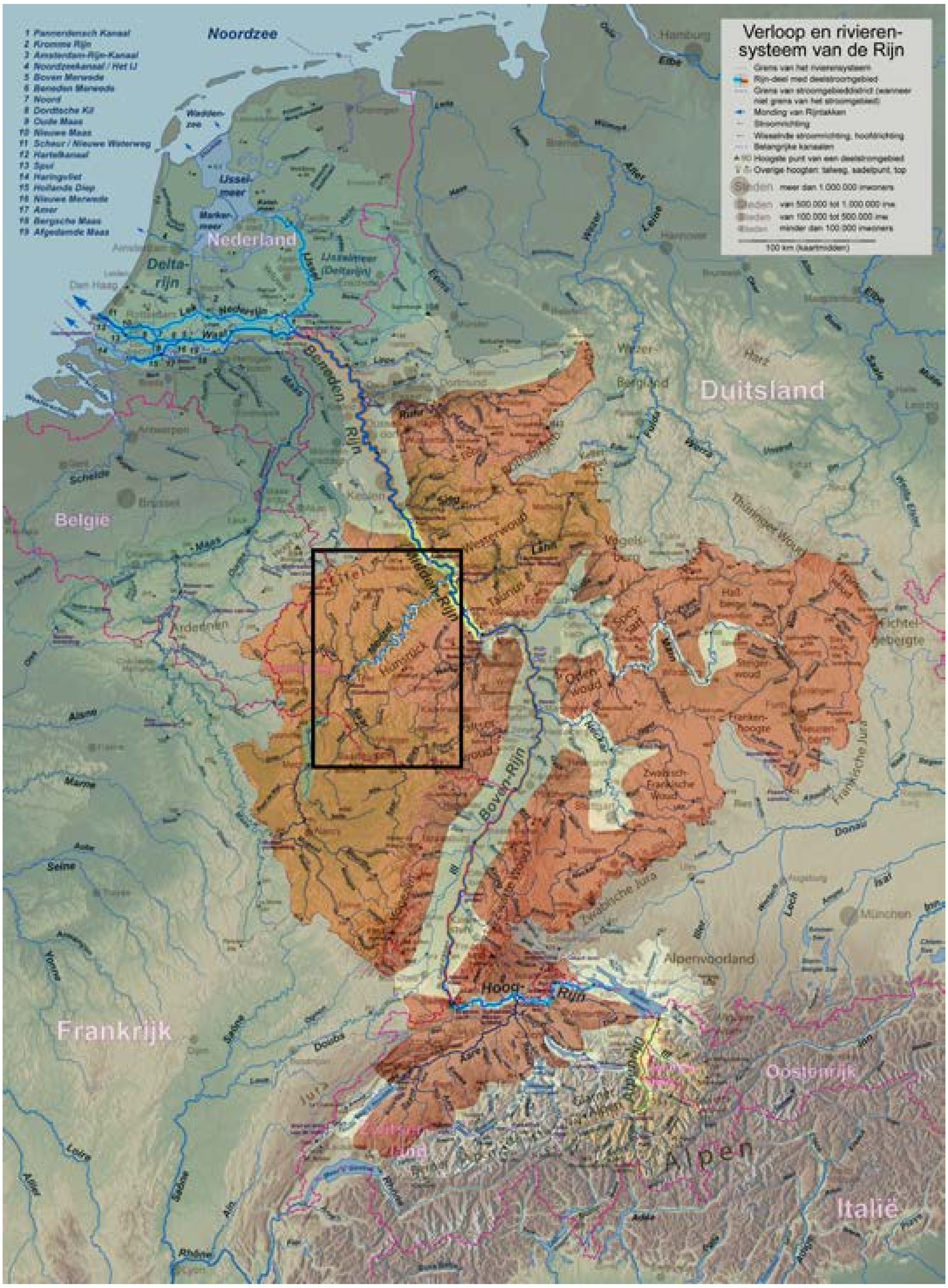


Figure 10. Map with Middle Mountains and box indicating Northern part of Mosel basin.

Step 3 Surface area of flat valley floors

In order to establish the surface area potentially suitable for natural retention 3 sub-basins in the Northern part of the Mosel valley were selected: the Prüm, Ruwer and Elsbach.

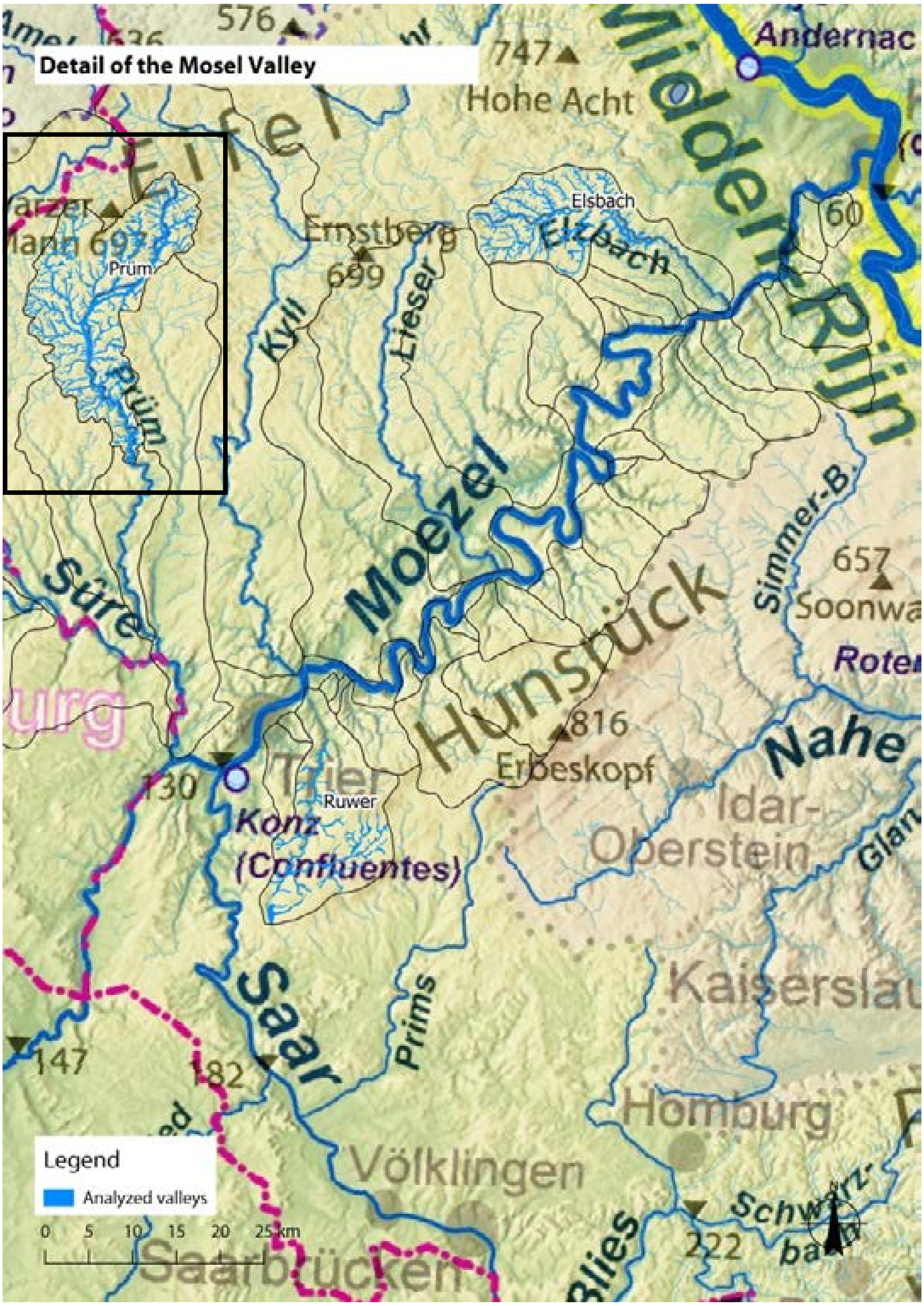


Figure 11. Map with location of the sub-basins. Prüm, Ruwer and Elsbach were analysed in this study. The box indicates the sub-basin of the Prüm, a tributary to the Mosel which in turn is an important tributary to the Rhine.

The steps taken to determine suitable valley floors are based on the analysis of land use and geomorphologic characteristics: slope and plateau versus valley floors. A suitable area was defined as an area with a slope of less than 10% and a GIS analysis was used to determine these areas (see box) in the valley-floors. It appeared that areas with low slope (<10%) covered 4.0 – 6.6% of the total basin area. (Table 1).

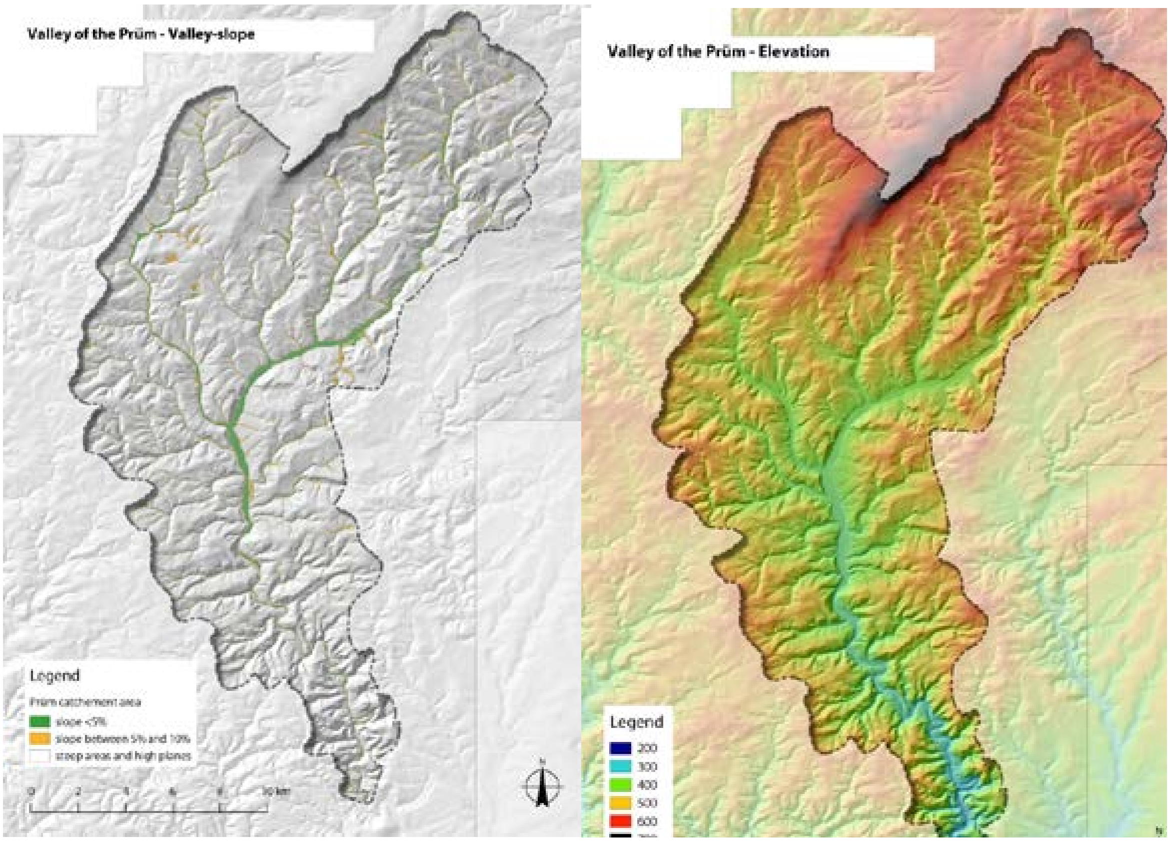


Figure 12. Maps of the sub-basin of the Prüm. On the left the elevation-map and on the right the areas with a slope less than 10% in the valley floors (green = 0–5%, orange 5-10%).

Table 1: Size of the areas with low slopes for 3 selected subbasins in the northern Mosel basin (manual method)

	Basin area (km^2)	Area of low slope (km^2)	Percentage of total
Prüm	310.7	20.1	6.5%
Ruwer	177.6	11.7	6.6%
Elsbach	172.7	6.9	4.0%

Identifying areas of low slope

On the basis of the Digital Elevation Map (cell size 25x25 m) sub-basins were selected which showed many small valley heads and valley plains (valleys having a flat bottom with some width). Subsequently, the slopes of the cells from this height map were determined using GIS. The cells with a low slope (<10%) situated in the upstream parts of the tributary valleys were selected and the surface area of the region with a low slope in the valley was determined. As a last step the built-up areas (cities, villages, roads) and areas of intensive agricultural use (e.g. orchards) were excluded because these are unsuitable for natural retention.

Step 4 Calculating retention potential

Now that we identified the areas with potential for sponge restoration, we calculated the retention potential in the three sub-basins by using a hydrological travel time analysis. Travel time influences the shape and peak of the runoff hydrograph:

- artificial drainage decreases the hydrological travel time, thereby increasing the peak build-up and peak discharge
- natural retention increases travel time and thereby reduces peak flows.

Two local travel time maps were created: one for the situation with the artificial drainage still in place and one for the situation in which artificial drainage is removed and the local travel time is increased (see box).

Calculating retention potential by travel time analysis

The hydrological impact (the assessment of peak reduction and increased storage) of sponge restoration is calculated by means of a hydrological travel time analysis. This analysis is based on the fact that from each location in a catchment, water has to travel a certain distance with a certain velocity to reach the outlet of the sub-basin. Locations further away from the outlet will contribute later while locations near the outlet will almost immediately start to contribute to the discharge of the catchment[21].

In the travel time calculation of the present situation all the areas in the sub-basin were given the same unit of time. In the calculation of the new situation where the drainage is removed, the areas with low slope in de valley floors were given a larger unit of time. Here we used a factor of 2 for the change in travel time. This doubling is an arbitrary value, there is generally no precise value for current travel time, nor is there a measured value available. However, we can assume that the changes in drainage situation should translate into a change in hydraulical resistence, which can be expressed by the Manning coefficient. And according to the Manning formula the velocity of water flow is inversely proportional to the Manning coefficient. It thus is clear that travel times are proportional to the Manning coefficient. Again, the exact values of the Manning coefficient are not readily available, but tables of empirically derived Mannings coefficients are available[22]*. The range of 2 used in the analysis covers the majority of variations in land use.*

Subsequently in a GIS-analysis the two local travel time maps were created for the entire sub-basins: one for the situation with the artificial drainage still in place and one for the situation in which artificial drainage is removed (see figure 13). In the next step the travel time from every location in the sub-basin to the outlet of the catchment was summed (see figure 14). The results for both analyses can subsequently be plotted in a synthetic hydrograph (see figure 15). This is a graph in which the discharge at the outlet of the sub-basin is given per unit of the time. From the differences between both lines in the hydrograph the difference in travel time can be verified.

It should be noted that the presented method shows that there is a potential for decreasing the peak volume by increasing the resistance, and thus increasing travel time. The exact peak reduction that can be obtained is by definition very dependent on the local situation. From a modeling perspective: this depends on actual manning coefficients, but more important, real peak reductions need to be established as measured values.

The resulting travel time maps are given in figure 13. The areas in the valley-floors with a slope less than 10 % and a larger unit of time are visible in the right figure. In figure 14 the total travel time for water from a certain location to the outlet is represented in 7 steps from large to short. The area with large travel times (coloured orange and light green in figure 14) become larger, the area with a short travel time (pink) becomes smaller.

21 Note that for this study we are not per se interested in the absolute value of the local travel time, but instead we are interested in the relative difference between the situation with and without drainage. Thus we can take a shortcut here and assume homogeneous distribution of travel times, in the sub-basin.

22 see for an example http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

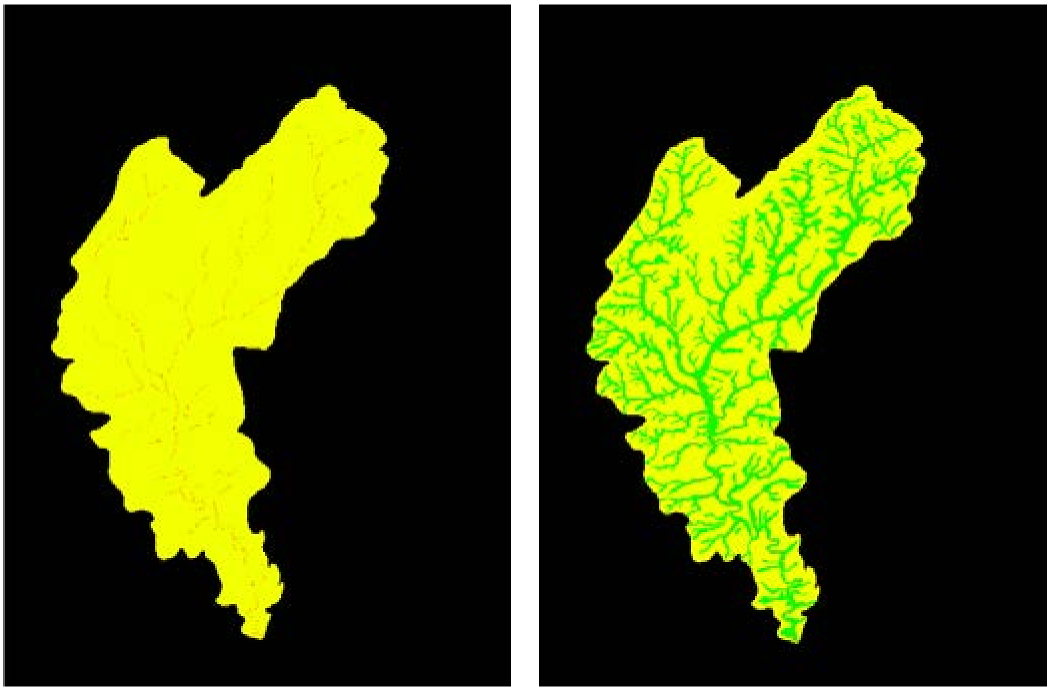


Figure 13. Local travel time for situations without (left) and with (right) increased travel time due to removal of drainage.

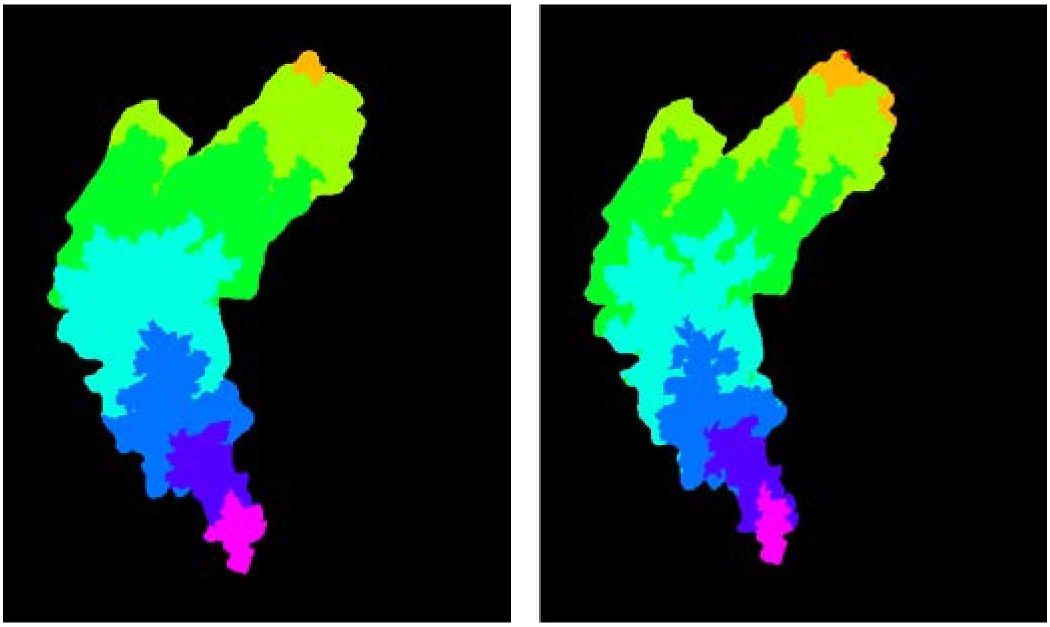


Figure 14. Total travel time maps from a certain location in the sub-basin to the outlet of the catchment. Left is the situation with the artificial drainage still in place and right is the situation in which artificial drainage is removed and the local travel time is increased . The travel time is divided in 7 equal steps from large (orange) to short (pink).The areas with large travel times (coloured orange and light green) become larger, the area with a short travel time (pink) becomes smaller.

The impact of the sponge restoration is an increase in travel times of the selected locations in the river valleys. This will, as per concept, also increase the travel times of the slopes and plateaus upstream of these river valleys, since all the water of these areas also passes the valley floors. The travel times for both calculations were plotted in a hydrograph. In this graph we see a clear difference of about 5-8 percent in peak discharge, due to the fact that all area with sponge restoration is delayed.

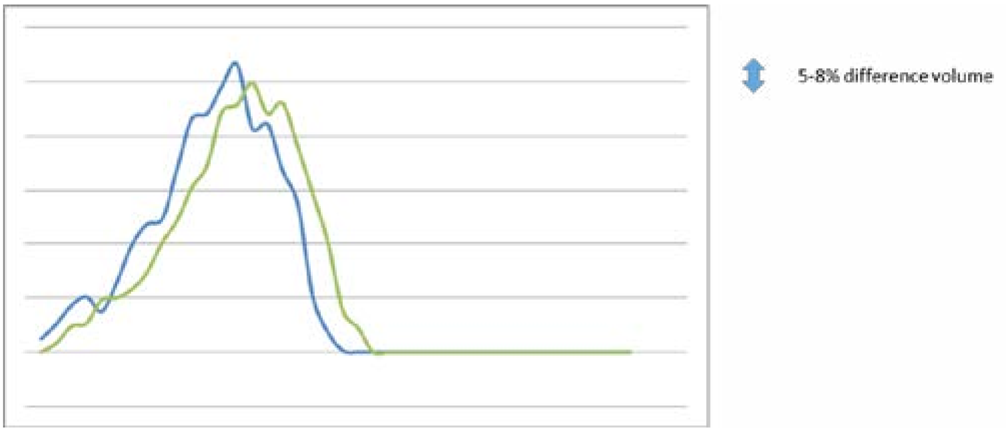


Figure 15. Synthetic discharge hydrograph based on the travel time in the Prüm catchment for situations without (blue line) and with (green line) sponge restoration. Y-axis = discharge X-axis = time. Development of sponges would lead to 5-8% lower peak discharges.

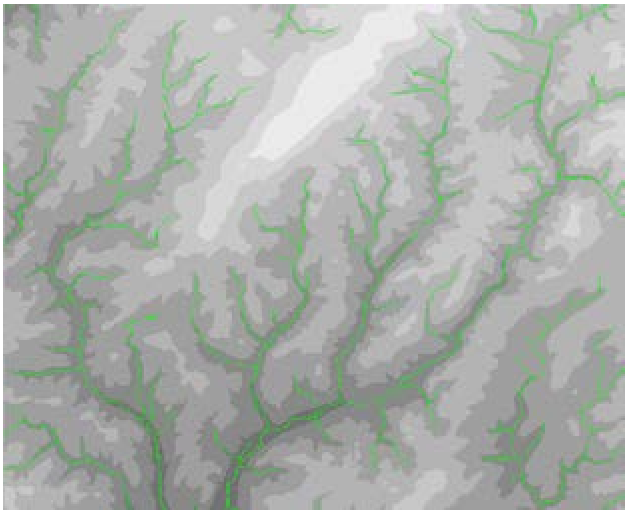
The results for the Ruwer and Elsbach catchments show similar hydrographs. For these results see part II of the annex.

PART II

Digital elevation flow path approach

The GIS approach outlined in part I yields very satisfactory results for the selected catchments. During the project the method was further refined by using a semi-automated way of delineating the valley floors of the catchments. The semi-automated approach uses readily available datasets for elevation and land use. SRTM (Shuttle Radar Topography Mission) data is used for elevation. This is a free and open data source for elevation data at a resolution of 30 meter, downloadable through https://earthexplorer.usgs.gov. The Corine dataset is used for land use, 100 meter resolution, hosted by the European Environmental Agency (EEA). From these datasets, the region of interest is selected, the data is cropped to cover only the area of interest, and an algorithm was developed to define valley floors and thus potentially suitable locations for sponge restoration. The land use dataset is subsequently used to subtract all urban areas and areas of intensive agricultural use from the potential suitable areas. The results achieved in this way provided a very good match with the results of the GIS approach as presented in part I of the annex and therefore can be used in future work. In this paper this new developed approach for delineating valley floors will be defined as the *Digital elevation flow path approach*.

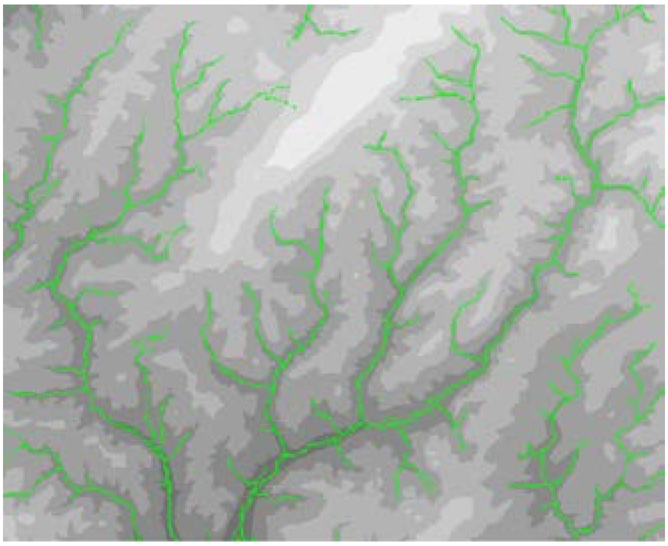
In GIS a relatively well-known technology is finding stream patterns in Digital Elevation Maps. ArcGIS knows procedures for Hydrologic Analysis, which help to find flow paths, catchment areas and flow accumulation, but other GIS tools such as QGIS and PCRaster know similar procedures.



These procedures are based on finding the steepest slope downhill for each gridcell in the gridded elevation map. Based on this steepest downhill slope the flow direction of each cell is determined: the direction in which surface water will flow downhill. By connecting all flow directions, we are able to construct a network map, yielding the drainage pattern based on elevation. Results are shown in figure 16.

Figure 16. Drainage pattern of the part of the Prüm as the results of traditional GIS hydrological analysis (see also part 1)

This analysis does yield the drainage network of the basin, but cannot be used to find the suitable valleys. However the suitable valleys have a wider valley floor, while non suitable valleys have a very narrow valley floor. We can use this characteristic to find different valley shapes. The method is to add a limited amount of noise to the Digital Elevation Map and see how sensitive the drainage pattern is for this noise. These steps of adding a little noise to the elevation and determine the flow direction and drainage pattern is repeatedly applied. At each step, the drainage pattern is determined. After a number of iterations (we used 50) we can determine where flow patterns remain relatively stable (regardless of the noise added to the elevation, the drainage pattern remains at the same location) and where flow patterns start to diverge. Well-defined drainage paths typically develop for streams in a narrow valley and they will remain relatively stable over the iterations. Ill-defined drainage paths, typically streams in wide valleys, will spread over the entire



valley floor, as the noise added in each of the iterations will have a relatively large impact on the drainage pattern. Two iterations of drainage patterns, of a noised Digital Elevation Map, are plotted in figure 17. In the valley floors, the drainage pattern of the two iteration starts to diverge, while the drainage patterns of the two iterations overlap in the steep valleys.

Figure 17. Drainage pattern of the part of the Prüm as the results of the newly developed Digital elevation flow path approach.

This methodology can be further refined by an iterative modification of the original digital elevation map, each iteration adding a new random noise field, determine drainage pattern and mark where streams are occurring. By counting the number of parts of a stream in each iteration, we get a pattern as displayed in figure 18. These maps greatly help in the visual interpretation of the Digital Elevation Maps to find suitable areas and can be used as a mask for the delineation of the potential sponge restoration areas.

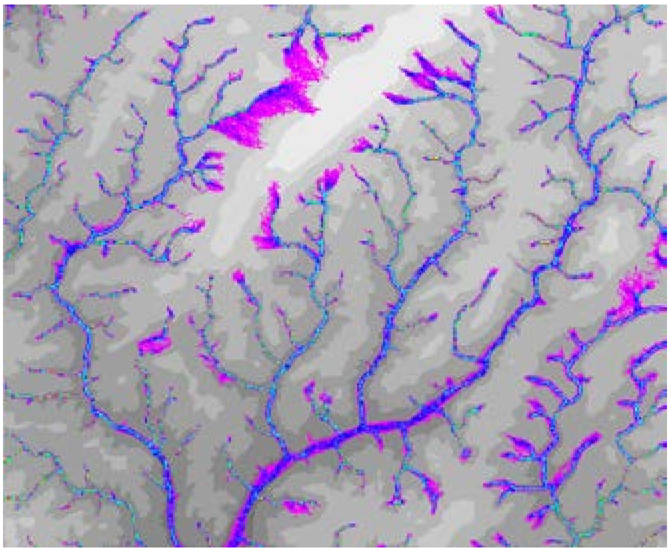


Figure 18. Number of hits for a cell being part of the drainage network for 50 noised digital elevation maps. From purple via dark blue to light blue the number of hits grows.

The Digital elevation flow path approach was applied on the sub-basins of the Elsbach and the Ruwer (see figure 19 and 21) and these maps were used as input for calculating the retention potential in the same way by means of a travel time analysis as for the Prüm catchment. The results of this travel time analysis are presented in the hydrographs for the Elsbach (figure 20) and the Ruwer (figure 22).

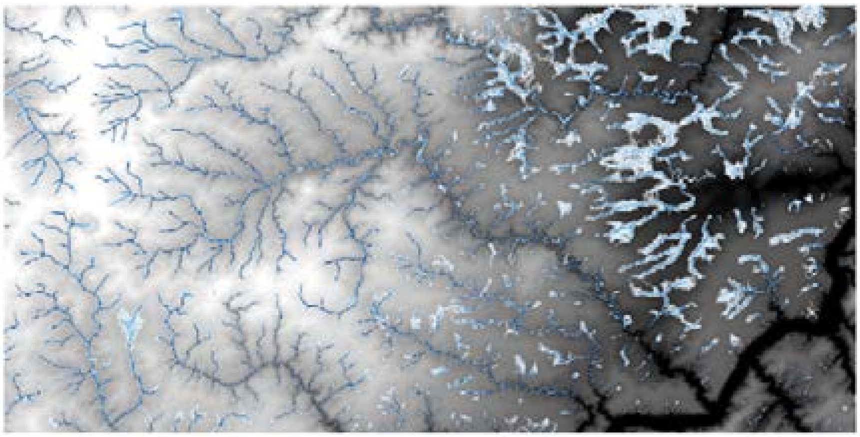


Figure 19. Results of the Digital elevation flow path approach for the Elsbach catchment.

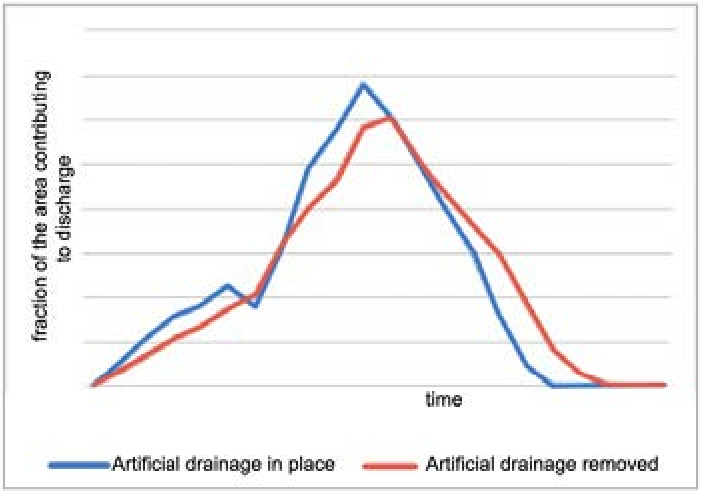


Figure 20. Synthetic discharge hydrograph based on the travel time in the Elsbach catchment for situations with (red line) and without (blue line) sponge restoration.

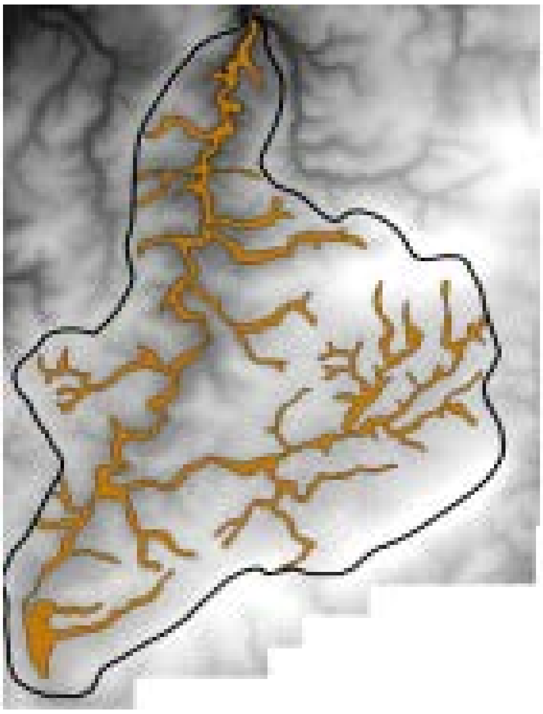


Figure 21. Results of the Digital elevation flow path approach for the Ruwer catchment.

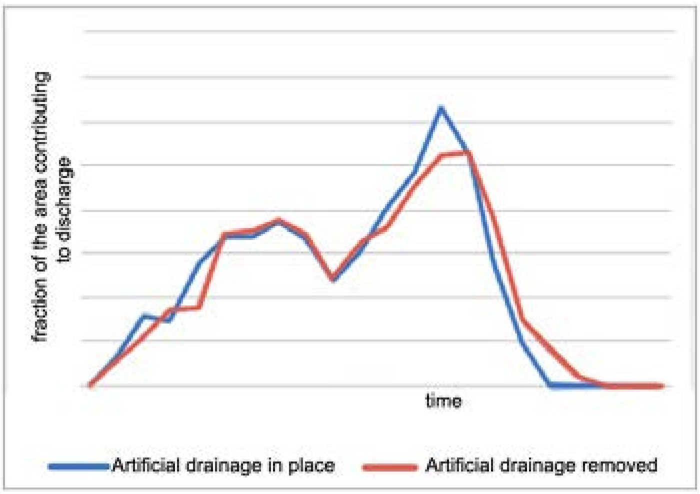


Figure 22. Synthetic discharge hydrograph based on the travel time in the Ruwer catchment for situations with (red line) and without (blue line) sponge restoration.

Annex 2. Carbon sequestration calculation

The potential for carbon capture are present but modest. An example calculation has been carried out for the Prüm catchment. Land use change from intensive to extensive agricultural production can lead to a capture of 595 tonnes of CO_2 equivalents. For a period of 20 years this amounts to 11,906 tonnes of CO_2 equivalents. If the same amount of land would be converted into forest, the climate impact for a period of 20 years would be 331,929 tonnes of CO_2 equivalents. Therefore land use changes in the Middle Mountain region will most likely not provide opportunities for selling carbon credits as a business model. However they do contribute to CO_2 reduction aims.

Calculation of the potential climate impact of sponges in the Prüm basin as an example

We based the calculations of the climate impact of sponge restoration in the Prüm study area on the Soil Mapping Units (SMU) and Soil Typological Units from the EU soil database. The climate impact of a sponge project is calculated in the spreadsheet Calculation Impact Impact Sponge Project Prüm (separate excel sheet available upon request).

The land use in the baseline consists of four types:

1. Non-irrigated arable land
2. Pastures
3. Complex cultivation patterns
4. Land principally occupied by agriculture, with significant areas of natural vegetation

Carbon dioxide

To determine the presence of mineral versus organic soils, we have looked at the Peat and OC_TOP parameters (Organic Carbon in the top layer of the soil, ie, 0-25 cm) in the corresponding EU soil database. None of the SMU's contain peat bases. The content of organic matter varies from very low to medium, meaning a content ranging from less than 1% to up to 6%. We assume that the entire pilot area consists of mineral soils.

Change in land use.

We have chosen two scenarios: 1) from arable land and pastures to extensive farming, and 2) transformation of arable land and pastures to forests. For both scenarios, only the baseline land use types are 'non-irrigated arable land' and 'patches'. For land use type 'complex cultivation patterns' it is not clear what the land use is exactly and whether it is suitable for changing land use. Land Use Type 4 identifies significant areas of natural vegetation. The precise share of natural vegetation is unknown and it is less likely that transformation into other land use has a positive climate impact. We have assumed that the transformation towards wetlands does not cause significant emissions, because the additional methane that is formed will most likely be compensated by the CO_2 captured.

Baseline emissions.

These are based on the assumption that the baseline situation is intensive agriculture. The corresponding emission factors from the IPCC 2006 Guidelines are based solely on nitrogen fertilization. The soils contain a low percentage of carbon dioxide and no oxidation of peat occurs. We have assumed that soil emissions are negligible because with the 1-year crops in the baseline scenario ('arable land'), carbon storage is negligible in the long term.

Project scenario.

In scenario 1 we assume a transition from intensive agriculture (arable land and pastures) to extensive agriculture. This results in reduced fertilization and therefore lower greenhouse gas emissions. In scenario 2 we assume a the transition from intensive agriculture (arable land and pastures) to natural forests. In the natural forest, in comparison with intensive farming, CO2 is captured by the growth of the forest.

In scenario 1, we assumed an increase in N_2O emissions between intensive and extensive agriculture. For this purpose, the IPCC 2006 data was used. In the calculations for Scenario 2 we assumed biomass growth data from natural young forest. The IPCC 2006 Guidelines do not contain data for plantation forests. Changes in carbon dioxide are also negligible in this scenario.

Result Scenario 1 - From Intensive to Extensive Agriculture

It is assumed that 1701 hectares of the 2010 hectare in the study area will be transformed. The climate gain per hectare due to less fertilization is low. For the total area, the annual climate impact is calculated at 595 tonnes of CO_2 equivalents. For a period of 20 years this amounts to 11,906 tonnes of CO_2 equivalents.

Result Scenario 2 - from intensive farming to natural forest

In scenario 2, the maximum conversion of 1701 hectares is also assumed. Climate impact is achieved by the loss of fertilization and the capture of CO_2 by growing forests. Every year, the climate impact is 18,656 tonnes of CO_2 equivalents. When calculating the climate impact over a given period, the biomass supply of grassland must be deducted from the climate impact of the project scenario. This is 24.75 tonnes of CO2 per hectare. For an area of 1664 hectares, this means a correction of 41,193 tons of CO2. The climate impact for a period of 20 years is 373,123 minus 41,193 = 331,929 tonnes of CO2 equivalents.

Risk of methane emissions.

When the groundwater level in an area is greatly increased, that can lead to emissions of the powerful greenhouse gas methane. This amount of methane is not included in the calculations, because it is unknown how many hectares of wetlands will be realized in the project scenario. In the final balance, these methane emissions from wetlands will lead to a reduction in climate mitigation potential.

Conclusions:

1. Due to the absence of peat bottoms or soils with a high organic content in the study area, the effect of avoided oxidation emissions is hardly present. This greatly limits the climate impact.

2. In scenario 1, the assumption is that all the current land use is intensive agriculture which can all be transformed into extensive agriculture. Even in this maximum and thus optimistic scenario, the effect on the climate seems to be low.

3. The transformation to forest in scenario 2 produces a climate impact of about 330,000 tonnes of CO_2 equivalents. This is the maximum achievable with full conversion to forest. In reality, this will be difficult to realize because of costs, desirability and local support.

Annex 3. Stakeholder analysis

Overview and Objectives

Resource management is often a critical component of regulating rivers, as it directly impacts many groups of stakeholders. River basin management methods cause differences of opinions, as they provide a source of drinking/irrigation water, the possibility for transportation, fishing, recreation, and may require flood protection methods.

For this project we gathered information about current resource management in the Mosel Basin by determining the opinions of various German stakeholders in regard to water retention areas, wetlands restoration and land use in the Mosel basin. This will provide an overview of the current situation. The stakeholder analysis accomplishes this using exploratory interviews and surveys to collect the necessary information regarding the influences and opinions of the various stakeholder groups. This process is accompanied by a literature review and a research of similar projects.

Methodology and Approach Part 1 of the stakeholder analysis

During the first two months, we focused on collecting information about the Mosel River Basin, its tributaries and the involved stakeholders. First, the stakeholders were categorized into groups (agriculture, municipalities/officials and organisations). Second, the Mosel River Basin was separated by its counties (Mayen-Koblenz, Cochem-Zell, Bernkastel-Wittlich, Trier-Saarburg, Bitburg-Prüm, Vulkaneifel and Ahrweiler). The main purpose was to survey, classify and rank all possible stakeholders (all governance levels, related sectors, companies and NGOs), and setup a database (in Excel). Relevant contact persons and key stakeholders (already in good contact with UDATA) were added to the respective groups and received a first information sheet (via mail) about the Sponge project. Third, the stakeholders were interviewed via phone. The interviews were fairly open and did not follow any specific structure: it was the major goal to collect information about awareness and knowledge about natural retention areas. However, a small survey was conducted including the stakeholder's name and organisation, their experience with similar projects in the past, the hydrological perspective, the awareness about the floodings and the personal thoughts about the project in general. Since it is still unclear whether and where a pilot region for water retention areas within the Mosel Basin will take place, all stakeholders have been questioned about potential sites. The first list of interviewees were researched online (mostly water authorities, universities, organisation webpages). All other contacts were recommendations by our key stakeholders and the interviewees.

During November and December 2016, the first stakeholder analysis was conducted including several interviews (partially in person) with key stakeholders. A detailed list of contacted persons can be found at page 62.

Furthermore, a detailed research of similar projects (finalised and on-going) along the Mosel River was conducted. The main results are projects implemented under the "Aktion Blau Plus" initiative. The program is funded by the Ministry of Environment and Energy, Food and Forestry of Rheinland-Pfalz and has its main purpose in restoring close-to-nature water bodies. Several projects in tributaries to the Mosel River have successfully been researched; water retention and local development have always been key issues.

Results part 1: Different opinions on the sponges approach

The results of the interviews conducted in the first part of the stakeholder analysis were as follows:

Within the **water sector** our contacts have different opinion about water restoring projects, depending on the administrative levels. The communities and municipalities are mainly positively minded whereas the ministries had more reservations about the potential success of the project. The reason is the scaling. Communities see the positive effect of community-building, recreation areas and the local flood protection of a restored river whereas the ministries look at the effect of big floods and see that few restored areas cannot hold the water of a 100-year flood. Besides, they claim that the Mosel basin has not a lot of flat areas for potential retention areas. On the municipality level, there are a lot of local projects in Rheinland-Pfalz in the "Hochwasserpatenschaften"-project (founded by the Ministry of Environment).

On the one hand, some representatives at state level (Ministerium für Umwelt, Energie, Ernährung und Forsten Rheinland-Pfalz and Saarland) do not see much hope for a success of the project. There are no potential areas, neither at the Mosel (deeply incised valleys) nor at the Saar River (densely populated, industrialized or already restored). They say most of the tributaries flow in v-shaped valleys which do not allow retention areas as flood protection. Some say that there are areas at some tributaries of the Saar, others do not agree. They also state that the effect to the Rhine flooding would be negligible for big floods. The ministry does have an own flood protection project which has problems with people's support and the proven insufficiency of the effect to the Rhine floods. On the other hand, representatives from Rheinland-Pfalz also encouraged the project and wished to integrate it in already running projects or re-start older initiatives, possibly in a follow-up project.

Land owners at the tributaries (mostly farmers) were rarely convinced by the project and are mostly not willing to give up their land for retention purposes nor sell it: according to representatives from agriculture, the Mosel-area has a lot of vineyards (high quality soil) which are split in several small pieces and belong to families for several generations. Disabling the drainage systems and giving up land for storage purposes can only be discussed if more concrete details about compensation can be provided. However, our interviewees mentioned that they are not affected by floodings (which is the case in the area around Trier) and therefore are not willing to sell in the first place.

An argument used quite often was that most of the tributaries come from the low mountain range, which means that there are no spacious valleys for restoration areas. There are just few flat plains for potential retention areas; the rest is v-shaped. Sources pointed out that maybe there are some suitable areas in France.

Organisations, universities and NGOs mainly suggested to review literature. Some publications from the International Commissions for the Protection of the Rhine (ICPR) or Mosel/Saar (IKSMS) investigated the potential of the Rhine's tributaries and came to the result that the effect of the drainage basin is negligible to the volume of the Rhine's water. Retention areas and technical flood protection in the basins show only a minimal effect. According to common ideas, especially during major floods, no effect is expected. The proportion of the drainage basin is too low and the tributaries show an upstream effect which could lead to an accumulation of the flood in case of retention. However, the report 'Possibilities for storage? Stores of possibilities!' written by Carthago and Stroming in 2013, provides counter arguments for this last argument (available at https://www.stroming.nl/overzicht/bergen-van-mogelijkheden).

Representatives from the IKSMS argued, that there would be no effect on the overall Rhine-water discharge during floodings even if all existing technical storages ('Polder') in the Mosel basin (as well as in the Saar basin) would be used for water retention. According to them, technical and natural measurements do not contribute to flood protection in the overall Rhine basin, but can reduce the local and regional flood risks. Furthermore, they have an effect on biodiversity and nature conservation. However, no exact water flow modelling has been conducted so far at the Mosel river due to several uncertainties and high modelling costs (sometimes the drainage process is not yet known, sometimes the models do not predict the real conditions). Quantitative statements are not yet proven and research is still necessary.

Concretization needed and focus on local effects

The authorities partly agree and disagree with the sponges approach. On the ministry level, some interviewees did agree with the idea of natural retention, however some others criticized the lacking impact on the overall Rhine basin. Nevertheless, the stakeholders working in administration think that rivers should get more retention areas in general. Local communities are more positively minded but only if the restoration has an effect on the local flood protection – flood protection for the Netherlands does not raise much interest. Farmers and representatives of agriculture are all sceptic towards the idea of selling/giving up land and need proper numbers before negotiating any further. Organisations and universities refer (similar to the ministry level) to the small impact/effect of such measures. In general, many stakeholders remained sceptical to the project, as they expected concrete facts and figures (e.g. costs, estimated area, timeframe), or because they considered exclusively ecologically oriented measures as ineffective on a large scale.

Methodology & Approach Part 2 of the stakeholder analysis

In mid-March 2017 the stakeholder analysis entered a second phase, in which the focus was placed on finding potential areas for a pilot project. This phase can be divided into three steps:

1. The compilation of a list of former projects
2. The establishment of contact
3. A hydrological analysis of potential sites

Each step will be briefly summarized in the following subsections.

1. First, a detailed list of former projects relevant to the sponges project was compiled through further research mainly in the internet. The list contained project name, planned measures, timeframe, funding, project partners, included tributaries and contact persons. All projects were categorized into two groups: 1. highly relevant projects 2. projects with intersections with the sponges approach.

2. In the second phase, at the beginning of the establishment of contact, responsible authorities for approval (SGD Nord/Süd) were contacted via phone to complete the list of former projects and find out about ongoing projects with connectivity options.

Then, the contact persons of first-category projects were contacted and openly interviewed about their experiences with the projects. At the end of each call, the contact person was asked about ongoing projects with connectivity options or, if not applicable, about his/her interest in a new project. In addition to that, UDATA sought further contacts. Subsequently, he/she was thanked and provided with an information sheet about the sponges project via mail, repeating the main questions of the interview. Depending on the preceding communication, the person was contacted again after a specific timeframe to find out about developments.

3. If a general interest existed, executing local authorities of potential project areas were directly contacted in a third step and offered a brief hydrological analysis on the potential tributary. Therefore, bounding boxes of the areas were created in *QGIS* and sent together with local runoff and precipitation data to our partners in the Netherlands for further investigation and a suitability test.

During the research, 24 previous projects were identified as relevant for sponges project, of which eight were put into the category “highly relevant” (see table 2 at page 58). Most of the former projects were accomplished in the framework of “AktionBlauPlus”, the follow-up project of Rheinland-Pfalz’s “Aktion Blau” which was established in 1995 by the 'Ministry of Environment, Landscape, Agriculture, Nutrition, Viticulture and Forestry' (MULEWF). It unites three major goals (compare MULEWF RLP 2015, p. 12f.):

1. The restoration of the ecological functional capacity of water bodies
2. The sustainable reinforcement of natural flood retention
3. The integration of further aspects of public interest

Further projects were funded by the federal government such as the German 'Federal Agency for Nature Conservation' (BfN), the 'Federal Ministry for the Environment, Nature Conservation and Nuclear Safety' (BMU) or the `Federal Agency for Transport and digital Infrastructure' (BMVI). One of the newest projects at federal level is the "Blaues Band Deutschland", which aims at the renaturation and dismantling of the infrastructure of side waterways since February 2017 until 2047*.* Five model projects along the river Rhine and Weser are currently under implementation.[23]

Projects were sorted into one of the two categories according to taken measures and specified aims. Those aims reach from high water retention, biotope protection to promotion of leisure and tourism. Ecological measures such as the renaturation of alluvial plains, dismantling of dikes or drainage systems were ranked higher than partly technical measures aiming only at flood prevention.

The river *Holzbach* originates at 415m over sea level in the north-east of *Steinen,* a small village in the district *Westerwald* and is 44km long. At 179m over sea level it joins the *Wied,* which is a tributary of the *Rhine* close to Döttesfeld in Rheinland-Pfalz. The river *Ruwer* is a 49km long rightern tributary of the *Mosel* in the low mountain ranges of the *Hunsrück* Rheinland-Pfalz. It originates at 650m over sea level near *Osburg* and surmounts 527m until its river mouth at 123m over sea level close to the city of *Trier*. The *Rur* is the only international river in the list: it is a rightern tributary of the *Maas* that originates in Belgium, flows through North Rhine Westfalia in Germany before it reaches its estuary in the Netherlands. During its journey, it overcomes 643m from its source at 660m over sea level until its estuary at 17m over sea level. Besides, with 165,4km it is the longest river of the potential project sites. The leftern tributary of the Mosel, the *Kyll,* is slightly shorter. It flows 127,6km from the *Losheimer Graben* at 660m over sea level within the low mountain ranges of the *Eifel,* in North Rhine Westfalia, to *Trier-Ehrang* in Rheinland-Pfalz at 123m over sea level. The *Olewiger Bach* is the smallest river that was considered for a pilot proj-ect. It is a 15,6km long tributay of the *Mosel* in Rheinland-Pfalz that runs from the foot of the *Hunsrück* mountain *Dreikopf* to the city of *Trier.*

Eight different project areas with potential were compiled, of which the five most promis-ing received bounding boxes: *Holzbach, Ruwer, Rur, Kyll* and *Olewiger Bach*. The following section will give a broad overview over the rivers. All rivers mentioned can be found on the map in figure 23.

23 http://www.blaues-band.bund.de/Projektseiten/Blaues_Band/DE/07_Modellprojekte/Modellprojekte_node.html;jsessionid=1A90FE3AF0A7E96C82E25F2930C7FB0D.live11291

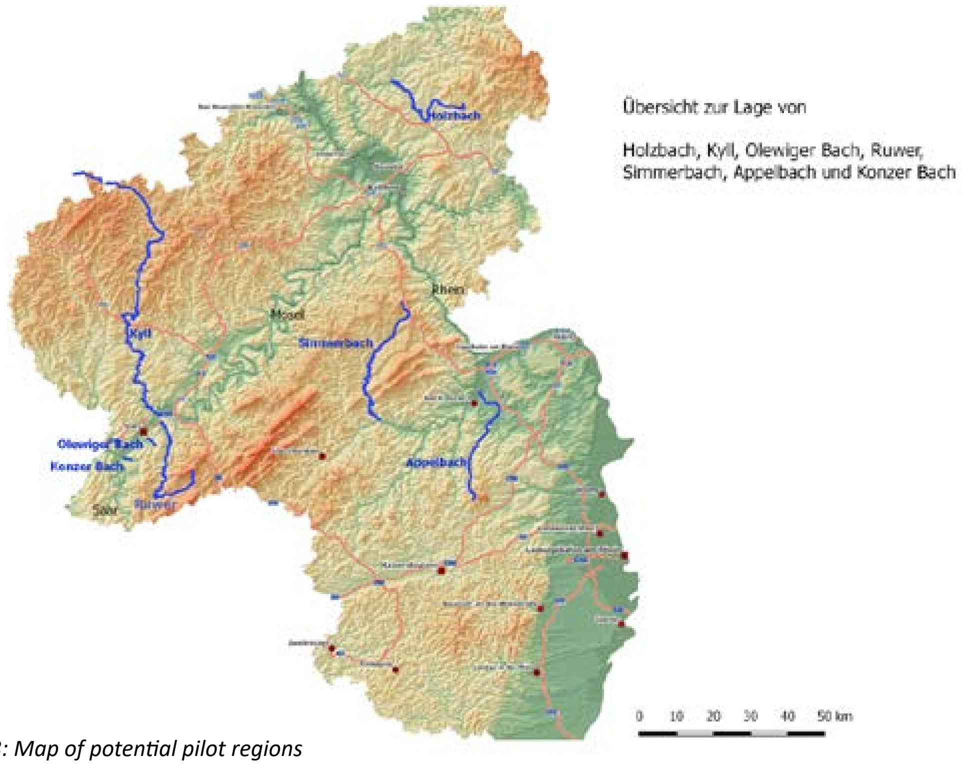


Figure 23: Map of potential pilot regions

Results Part 2: Related projects provide promising contacts for future cooperation

Conversations with district and municipal administrations turned out to be more promising than talking to higher levels: many stakeholders showed a great openness and interest in the project. The following chart shows an overview about relevant projects and locations in the Mosel basin where our contacts can imagine a possible cooperation with the sponges project.

Project/Tributary	**Location**	**Comments**
Holzbach	Neuwied	Contact successful and interested, on-site meeting is possible.
Ruwer	Kell am See, Trier-Saarburg	Willingness to raise awareness about the topic in regular meeting with the local authorities. Would be interested in an implementation of the project in the second half of 2017.
Obere Rur	Euskirchen, Nettersheim	Contacts are really keen on the project and see optimal conditions at the Obere Rur.
Kyll	Kyllburg, Vulkaneifel, Gerolsteiner Land	Contact suggested cooperation so both sides can benefit from each other.
Olewiger Bach	Trier	Contact is interested and suggests a meeting together with the University of Trier which is currently analyzing frequently occurring flood peaks in the area and therefore has installed several measuring stations in the water body.
Konzer Bach	Konz	Contact suggested cooperation so both sides can benefit from each other.

Simmerbach	Birkenfeld	There are a few projects that will be implemented in the next time.
Appelbach	Bad Kreuznach	Contact is very interested in the program. There are active renaturation measures at the Appelbach. Another contact was also very open-minded regarding the project. Potential areas could be the Alsenstal, Krevenbachtal and Ellerbachtal, all "second rank" water bodies.

Table 2. Overview of the eight most relevant pilot regions

As already mentioned, a detailed list with all contacted stakeholders can be found further down in this annex at page 63. Here, only the closest contacts and only areas with high potential were referred to in order to maintain an appropriate length of the report. However, the establishment of contact involved a lot of other persons.

A good example of a project of high relevance for the sponges project is the renaturation of the Kyll estuary. The river Kyll is a tributary to the left of the Mosel and the longest river in the southern Eifel. It has its source in the forest Zitterwald close to the Belgian border in the federal state of Saarland at approximately 660m above sea-level and joins the Mosel after around 130km at approximately 123m over sea-level near Trier-Ehrang. It is the largest inner-German river in Rheinland-Pfalz and the only side river of the Mosel, whose estuary is located outside of settlement areas. The project of NABU Trier and the University of Trier implemented between 2008 and 2012 focussed on the redesign of the estuary by reconnecting abandoned channels, pre-structuring flood channels and synclines, as well as planting alluvial forest. It was categorized as highly relevant because of the rivers location in the low mountain ranges of Rheinland-Pfalz, its water wealth and the integrative approach combining different ecological measures. Figures 1 and 2 show the estuary before and after the implementation of the project. A complete list of all the relevant projects to the sponges project can be found in the annex (in German).

Figure 24: The Kyll estuary before the project (BGH Plan GmbH)

Figure 25: The Kyll estuary after the project (BGH Plan GmbH)

One of the stakeholders informed us about the project "Ecologically oriented Flood Protection Steinheim-Ralingen". The project was implemented in German-Luxembourgian cooperation between 2009 and 2012 at the river Sauer and represents one of the few trans-national projects on ecological high water retention in Germany. Detailed information including the approval planning was sent on three CDs and can be provided upon request. Nevertheless, when being asked about any interest in implementing a new trans-national project, the answer was firmly negative: projects of this dimension would be expensive, so no further plans would be made at that point.

Focus on local flood protection, nature conservation and community projects

The second stage of the stakeholder analysis was more promising compared to the first one. A thorough research for relatable projects (mostly former or current "AktionBlau"/AktionBlauPlus" initiatives) and direct contacts to the responsible project managers led to a more positive feedback. The eight above mentioned rivers were the most relevant projects that had/still run similar approaches to the sponges approach and where the representatives could see opportunities for co-operation. Depending on funding and the correct basic requirements (e.g. slope elevation), these areas could be potential pilot regions for the implementation of the sponges method. We concluded that focusing on the Mosel basin on a small-scale level and focus on impacts on local flood protection, nature conservation and community projects is far more effective and goal-orientated compared to working on a state-wide level focusing on the whole basin and including the impacts on the Netherlands.

Recommendations and Lessons Learnt from Stakeholder and Advisory Board meetings

Advisory Board & Stakeholder Meeting in Mainz, 23 June 2017

Issues discussed:

Aim for the follow-up project

- International projects like the Sponges project are interesting to raise political awareness ("even if the concept wouldn't work technically"). Dutch interference could enhance the 'source to sea'- thinking / basin approach as well as re-naturalization projects.
- More research is needed to understand (re)naturalization in water management. How to restore, how to steer, how much space is needed, how to apply multifunctional use to areas, how to work internationally. Also, we need to develop a vision on "our life" 100 years from now; how will water be integrated in the landscape, will we have a cultural landscape or alternative. This should help initiate the discussion on the contribution of re-naturalization to flood safety. Opinions differ, there is a strong agricultural lobby. Science, politics and donors need to be convinced.

Effect of the project

- Stakeholders question whether the sponge restoration measure would have effect on the water level in the Netherlands. Flooding is a problem in the region itself.

Space available and land use

- Is there enough space available to realize the concept? The agricultural sector is facing a decrease in the availability of land due to urbanization. The need for space is extreme; prices have gone up in recent years. Natural Water Retention Measures such as the sponge restoration measure would add more pressure on the availability of land. Land acquisition is difficult; it would only work if drainage is maintained so the land can remain functional. But this contradicts the sponge concept.
- Cultural aspect is important: agricultural land use has been in place for centuries, people are attached to the landscape as it is.
- In discussion about land use, it is said that there is 40% of land use for agriculture, 40% forestry, 5% nature, but water is not included. What does that mean for our place in the landscape? These calculations contribute to the way the politics communicate about land use.

Funding opportunities?

- Some German authorities prefer to use their own funds for water management programs, as European funded projects do not pay off anymore. This applies to European funding for agriculture too.

Recommendations

- Include several aims (ecological, flooding etc.) in one project
- Take the agricultural sector onboard (politically)
- Join an existing initiative or program (maybe within an area that is already environmentally protected) and learn in terms of recreation, retention, ecological aspects.
- Project with 'what if…' scenarios (due to modeling different parameters)
- Use re-naturalization for flooding protection – Aim: Benefits for nature AND people
- Cooperate at the national level with the Federal Institute of Hydrology (BfG) under the Federal Ministry of Transport, Building and Housing. They are very competent in modelling.
- The concept sounds sympathetic but there is no sympathy; generate proof of your hypothesis.
- Blaues Band is an initiative that has just started. The aim is to redevelop former navigable rivers for recreational and ecological use. It is a long term programme with a budget of 50 million euro per year of earmarked money from national government.
- Living Lahn Life IP does some actions for renaturation, they're open for ideas. The coming 9 years they will develop a concept on the shift from navigation use of the river to ecologically restored river. Some no-regret measures may be implemented. It is an open process in terms of what will come out of it.
- University of Hannover looks at nature-based solutions in the Life project. Perhaps cooperation will be possible.

Meetings with Advisory Board Members not able to attend the meeting in Mainz

Issues discussed

- The business case of sponge restoration equals the benefits of avoided (infrastructural) measures. It would only be effective in case of large scale conversion of agricultural land to wetland.
- Arguments questioning the effectiveness of sponge restoration;
    - an extreme scenario in a larger, heavily urbanized area covering the entire basin could indeed show no effect in models.
    - Also, slowing down discharge at the foot of the valley still means part of the water will pass by and flow directly into the stream. This nuance is not included in current line of reasoning.
    - There are still some doubts about the effectiveness of the measure at basin level
- Internationally, the ICPR is a model for transboundary cooperation.

Recommendations

- Incorporate the agricultural sector, create the feeling that they're part of the strategy, the way forward. They should be compensated or incentivized. Connect them to issues such as storage, quality and availability of freshwater. Consider to adopt a pioneering role aiming to close the gap between nature/water managers and farmers.
- Beside a focus on flood risk reduction, include the issue of water scarcity, which is becoming more urgent under various climate scenarios due to diminishing discharge from glaciers.
- Ask yourself: where do we want to be in 2-10 years from now? Make vision and steps concrete.
- For upscaling the concept, it will be necessary to include a market or business model, e.g. 'delivery of water storage services', 'market for supply of and demand for water buffers'. To achieve a proper upstream/downstream financing mechanism, evidence of the effectiveness of the measure is needed.

- The scale of the concept makes implementation challenging. Harvesting local effects provides a better business case than focusing on achieving results in the main river.
- Consider a local business / governance case. It will lower the hurdle for a pilot project.
- Another idea: aim for local demonstration projects for example near the border between Germany and Netherlands, in the middle reaches of the Rhine basin and in Switzerland. At higher level these project are connected, but implementation and effects are first and foremost local.
- On the assessment whether to start with a demonstration project or to start with calculating the effects to provide evidence: the Dutch and German authorities may take different approaches. Both are possible options to achieve the same result.
- There are many existing similar initiatives in Germany (and the Netherlands). It would be interesting to map these and collect data.
- Be clear about the insecurities and vulnerabilities of the approach otherwise 'our' opponents will use them against us soon enough.
- Be clear that it is part of the solution and that it has additional societal benefits.
- Make scenario's of measures : from exentensifying agriculture with compensation to full nature development and let it depend on the local situation which one to choose. Be clear about this from the beginning that it is not 'us against agriculture'.
- Think about extending our ideas to eastern Europe, also in Poland a lot of area is drained.

Organizations contacted in phase 1

Project/ Water body	Location/Organization involved
Tributaries around Trier	SGD Nord Regionalstelle Trier
Tributaries in the Südpfalz	SGD Süd Regionalstelle Neustadt
Tributaries around Schweich	VG Schweich
All across Rheinland-Pfalz	SGD Sued Regionalstelle Mainz
Seegraben, Pfrimm, Eisbach	Stadtverwaltung Worms
Ohmbachaue	VG Oberes Glantal- Fachbereich Bauen und Umwelt
Model project Grenzbachtal	LK Neuwied - Abteilung Bauen und Umwelt
Renaturation Lauteraue	Stadt Kaiserslautern
Naheprogramm: Simmerbach	LK Birkenfeld - Abteilung Bauen und Umwelt

Tributaries around Idar-Oberstein	Dienstleistungszentrum Ländlicher Raum - Rheinhessen-Nahe-Hunsrück - (DLR)
Responsible for: Nette und Krufter Bach; Elzbach; Brohlbach; Saynbach; Brexbach	Landkreis Mayen-Koblenz: Gewässerunter-haltung
Responsible for: Salm, Kailbach, Dhron, Kleine Dhron, Lieser, Kleine Kyll, Alfbach, Ueßbach und das Meerfelder Maar	Landkreis Bernkastel-Wittlich: Wasserkraft
Sauer, Our; Kyll, Prüm etc	Eifelkreis Bitburg-Prüm: Hochwasserschutz
All across Rheinland-Pfalz	Landwirtschaftskammer Rheinland-Pfalz: Koblenz
All across Rheinland-Pfalz	Landwirtschaftskammer Rheinland-Pfalz: Trier
All across Rheinland-Pfalz	Landwirtschaftskammer Rheinland-Pfalz: Wittlich
Germany	NABU Deutschland
All across Rheinland-Pfalz	NABU Rheinland-Pfalz
All along the Mosel and Saar	IKSMS
All along the Rhine	IKSR
Saarland	Ministry of Environment, Saarland
Rheinland-Pfalz	Ministry of Environment, Rheinland-Pfalz
Rheinland-Pfalz	Landesamt für Umwelt, Rheinland-Pfalz

Organizations contacted in phase 2

Project/ Water body	Location/Organization involved
Ruwer	Community Admin. Kell am See
Ruwer	District Admin. Trier-Saarburg
Obere Rur	District Euskirchen
Kyll	Hömme GbR
Olewiger Bach	Hömme GbR (CEO)
Olewiger Bach	City Admin. Trier
Konzer Bach	Hömme GbR (CEO)
Appelbach / other water bodies in the district Bad Kreuznach	DLR Rhinehessen-Nahe-Hunsrück
Appelbach / other water bodies in the district Bad Kreuznach	District admin. Bad Kreuznach

Advisory Board members

NAME	ORGANISATION
Christoph Linnenweber	Head of Hydrology LfU Rheinland-Pfalz
Gebhard Schüler	Forschungsanstalt für Waldökologie und Forstwirtschaft (FAWF) Rheinland-Pfalz /Ministerium für Umwelt, Energie, Ernährung und Forsten Rheinland-Pfalz
Gerhard van den Top	Chair of the Regional Water Board, Amestel, Gooi & Vecht
Patrick Meire	University of Antwerp, Professor Ecosystem Services,
Erik van Slobbe	Wageningen University, Water Systems and Global Change

Organizations represented at the Stakeholder Meeting Mainz, 23 June 2017

ORGANISATION
University of Trier
IKSR
Stiftung Natur und Umwelt Rheinland Pfalz
Landesamt für Umwelt Rheinland Pfalz
Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz
Planungsbüro Hömme GbR
Stroming
Wetlands International- European Association
University of Wageningen
UDATA GmbH

Annex 4. Literature analysis

During the project, three interns from different universities have contributed to the literature anlaysis.

Stakeholder involvement in transboundary water resource management projects

Joeri van der Stroom from Wageningen University has carried out a literature analysis of stakeholder involvement in transboundary water resource management project. The most relevant part are stated here. The total literature overview is available upon request.

Implementation of wetland restoration projects in Sweden

In a document about the lessons learned from implementation of wetland restoration projects and stakeholder engagement in Sweden (Andersson, 2012), several important aspects about stakeholder engagement become apparent. They mention that key identified factors in all wetland restoration projects are:

- The involvement of different actors.
- Maintaining a local presence.
- Development of long-term dialogue with farmers.

Additionally, the multiple benefits of wetlands need to be recognised by farmers. This could then on its turn result in incentives for farmers to have wetlands on their land. For example if wetlands can be used as irrigation reservoir, they can use this too during their agricultural activities, but the wetlands can also function as a flood-buffer and improve nutrient retention. In general farmers are interested to the improvement of the environment, while environmental authorities often see farmers as having a negative impact on the environment.

A challenge is however to upscale wetland restoration projects instead of only implementing them at the local scale. As an advice the authors mention to consider a basin perspective and engage new actors and sectors. Also guiding frameworks for larger project schemes are necessary to be developed and the financial support needs to be adapted to larger projects.

IRMA (International Rhine Meuse Activities)-program

Another example of a transboundary program is the IRMA (International Rhine Meuse Activities)-program. This program, which dates from 1996, consisted of regional projects and was financed by the European commission (Boelhouwer, 2003). Within this program, the Dutch government invested €10 million EU money in retention areas and dike replacements in Germany under the name IRMA-SPONGE (Hakman et al., 2014). In a document of the results of this program (Hooijer et al., 2002), it is mentioned that decision makers should focus on implementing retention areas near the downstream areas and not too far upstream as this will not have an effect on extreme flood events due to prolonged rainfall over large areas. The areas available for this measure along the Rhine are insufficient and to contribute to the attenuation of extreme events, they can however be functional for low to medium flows.

What is mentioned as a result of this research concerning collaboration between different countries is that (Hooijer et al., 2002):

- Differences between regions should be taken into account; the river changes along its course, but also economic and cultural values or ecological functions can be different.

- If a transboundary network is set up, make sure the network is kept active. Transboundary cooperation requires understanding and this is only possible if people are cooperating within a long term international and interdisciplinary network.

- Certain terms can be misinterpreted by people from different countries; therefore standardize certain terms and concept in the early stages of collaboration.

- Clear target groups for the results of research. If there is a clear target group, the research can be targeted better and therefore research results can be communicated better.

Sufficient funds on the German side is not a big obstacle in implementation of these kind of measures. The problem is that there is a lack of strong regional or provincial governments who have access to available funds who can coordinate investments autonomously (DHV rapport). With measures like retention areas, public opinion plays a larger role than money. Also funding measures with Dutch tax money outside the Dutch border is seen as a sensitive subject among Dutch waterboards (DHV rapport). Using European funds for this can be a solution for this issue.

Farmers and flood retention areas

Wageningen University has published a document about water knowledge, policy and politics concerning areas of land that flood in case of emergencies (Roth et al., 2006). In this document there is a section about the obstacles during the participation of farmers in the creation of these kind of areas on land that is in possession of the farmers. It is mentioned that citizens do not want to look at an ugly dike in the back of their garden, but they also do not want to provide the space the governments tries to claim as a response to the negative reactions towards the dike for the creation of retention areas. The citizens completely trust the government but the government tries to make clear to the citizens that total safety against floods is impossible to guarantee. Also it is mentioned that some farmers are very happy to get money for their land if it is turned into an emergency flooding area, but others will not be happy with big investments that do not guarantee 100% safety. Sometimes farmers resist against the government if they want to buy or compensate for the use of their land, because if you resist it strengthens your bargaining position and the ability to gain more money. Also the farmers do not fully trust the government when it comes down to receiving the compensation if their land does get flooded in an emergency. These examples are all government initiatives, but when an NGO tries to implement such a measure, the obstacles can be similar.

Models, storage and flow properties

Elena Raudasch and Vera Middendorf from the Universitty of Tübingen also did a literature research. Available literature focusing on models and storage and flow properties were put together, systematically analysed and reviewed on its relevance for the Mosel Basin. The most relevant conclusions are summarized her. The full review is available upon request.

The literature analysis' main focus was on:

- Hydrological processes in storage bodies
- Flood modelling
- Effectiveness of natural retention

The most important conclusions of this research were

A lot of literature dealing with ecological flood prevention has been reviewed. Although the authors come to varying conclusions, there are several aspects that they have in common. First of all, most projects successfully implemented focused on local flood prevention measures so far. They are considered effective and useful for the protection of small-scale risk regions and the mitigation of small flood events. However, the volume that can be held back by local measures is evaluated to be not sufficient for a significant effect on the superordinate river system. In addition, the positive effect is said to vanish as soon as quick, very high flood waves, such as historic flood events appear.

One of the authors considers tributaries irrelevant for flood protection in general. With regard to the concrete types of measures, dyke relocations for recovery of flood plains are assessed the most effective. Although the same difficulty applies to this measure, an important additional benefit appears with the renaturation of meadows: the improvement of biodiversity in the respective area.

In the catchment areas of the rivers Rhine, Mosel and Saar it is stated that not enough potential flood areas are available to have an impact on flood prevention. One author suggests taking on-site measures in the Netherlands in order to solve the issue of flooding. It can as well be recorded that large-scale projects need to be commenced for greater impacts on flood protection on a large scale. Therefore, major challenges like the coordination across regional and disciplinary boundaries have to be met in future.

The literature review reflects the fact that currently the proposed methods for sponge restoration is not viewed as very effective for large scale flood management. We commented on these viewpoints in our study 'Possibilities for storage? Stores of possibilities!' written by Carthago and Stroming in 2013, , and we made a case to gain more experience with the integrated basin approach as advocated by many experts, and treat the sponges approach of restoring local buffer capacity in large basins as one of the promising alternatives for flood management. Local effects may be expected, but these local effects average out in a large basin such as the Rhine basin. This is of course true for the contribution of each individual projects, but the combined effects of a large number of projects is less well studied.

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