# Barriers and opportunities for Nature Based Solutions in the flood risk management of small rivers in Limburg

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**Abstract**
Floods are forming an increasing problem in the Netherlands. Recent events have shown that these floods do not only occur in large river systems, but also in smaller rivers they cause significant damage. Nature Based Solutions (NBS) present a relatively new approach containing measures that use natural processes to lower flood risks. The aim of this research is to use the case of Limburg, the Netherlands to analyse which governance and landscape barriers and opportunities impact the uptake and implementation of NBS in Flood Risk Management (FRM). This research addresses this by analysing grey literature, expert interviews and GIS-bassed mapping. The results show that institutional fragmentation, stakeholder conflicts, the lack of available land and a lack of evidence about NBS effectiveness are the most dominant barriers in the uptake and implementation of NBS. The analysis also suggests that the interaction between governance and landscape barriers strengthens these barriers. The research concludes that opportunities for NBS lay in the development of integral supportive policies that consider both landscape and governance factors. This requires however, greater insights into the effectiveness of NBS measures.

# 1. Introduction

Floods are a serious climate related risk in Europe, also in the Netherlands which is highly vulnerable because of its dense population and multiple river systems. In 2021 Western Europe was hit with one of the biggest flood events in a decade (Lehmkuhl et al., 2022). Events like this are likely to happen more frequently in the future because of the change in climate (Arnell & Gosling, 2016). The floods in Limburg showed that not only large rivers, but also smaller rivers like the Roer, the Geul and the Geleenbeek can cause serious damage (Figure 1). Most damage occurred along smaller rivers in Limburg, causing the destruction of homes, infrastructure and local economies (Asselman et al., 2022) (Kok et al., 2023). The disaster showed that flood risks are not only problematic in larger rivers, but also highly affect smaller rivers. Municipalities, the province and water boards have to balance urgent investments in flood protection with other demands for building housing, land-use and economic development. This makes the investigation and development for resilient, sustainable, cost effective, and socially accepted measures an important societal issue.

***Figure 1.*** *Flood impacts during the 2021 flood event in Limburg. Source: Waterschap Limburg (2021).*

The 2021 floods can be seen as a window of opportunity for a new approach in flood risk management in Limburg. Nature Based Solution (NBS) is a concept that is gaining popularity in the last few years. NBS are solutions that are inspired and supported by nature which bring environmental, social and economic benefits (*European Commission*, 2025). In this context this means, besides reducing flood risks, they can better ecological quality, provide options for recreation and contribute to climate adaptation (Turkelboom et al., 2021). However transitioning to nature based river management is a complex governance challenge, due to a range of barriers that arise in the implementation of NBS (Raška et al., 2022) (Vojinovic et al., 2021). These include landscape barriers, but also governance barriers. Additionally, there is a gap in NBS ambition and actual implementation of NBS (Martin et al., 2025) and Slager et al. (2022) argue that there is an urgent need for more extensive facilitation and research at NBS in Limburg.

NBS are extensively discussed in academic literature, but most research and concrete examples are about large rivers or placed in an urban context (Frantzeskaki, 2019) (Chen et al., 2021). These studies explain the benefits of NBS for flood protection, ecology, and society, but they give limited insights into their uptake in small rivers. Also, governance and landscape factors are rarely studied in combination, even though it can give a more complete understanding of the barriers for NBS.

Therefore, this research aims to address this gap through analysing how the governance and landscape factors together influence the uptake and implementation of NBS in small rivers in Limburg. By looking at these two different dimensions in combination, this study contributes to a more complete understanding of the barriers and opportunities for nature

based flood management in small rivers. *The main research question in this research is: What governance and landscape barriers influence the uptake and implementation of nature-based solutions in the flood risk management of small rivers in Limburg?*
To answer this question, the following sub-questions have to be answered first.

1. What are NBS in relation to flood risk management in small rivers?
2. Which governance and landscape barriers and opportunities affect the uptake and implementation of NBS in small rivers?
3. How do the combination of these barriers and opportunities influence the uptake and implementation of NBS in small rivers in Limburg?
4. What lessons does the Limburg case teach for implementing NBS in small rivers in similar contexts?

The remainder of this thesis is structured as follows: First, in chapter 2, the theoretical framework is described which ties it to existing literature. After that the methods used for this analysis are described in chapter 3. In chapter 4 the results are presented. Chapter 5 discusses these questions in relation to the main research question and chapter 6 concludes the research by summarizing the findings and describing policy implications and suggestions for future research.

# 2. Theoretical framework

In this study three concepts are central: (i) Nature Based Solutions (NBS), (ii) Governance barriers and opportunities, (iii) Landscape barriers and opportunities. These concepts are based on existing literature and together they provide the analytical framework to examine the uptake and implementation of NBS in small rivers in Limburg.

### 2.1. Nature Based Solutions in Flood Risk Management in small rivers

NBS are solutions that are inspired and supported by nature, which are cost effective, and simultaneously provide environmental, social and economic benefits (Nature-Based Solutions - European Commission, 2025). Although forms of NBS are widely used in policies, the concept is not always formulated in the same way (Albert et al., 2021). It overlaps with different terms such as green infrastructure or working with nature. In this study, NBS are measures in river systems that reduce flood risks by working with natural processes. Examples are defined as floodplain restoration, wetland creation and re-meandering among others (Raška et al., 2022). These measures are different from traditional technical measures because they are multifunctional, they do not only reduce flood risks, but also increase biodiversity, and have social and economic benefits (Turkelboom et al., 2021).

In the context of small rivers, NBS are different then measures in larger rivers. According to Vojinovic et al. (2021) the effectiveness of NBS is dependent on the scale of the measure and the river system in which it is implemented. For small rivers, this means that effects are dependent on how measures are scaled within the river system.

In this study, flood risk management is based on the framework that Hegger et al. (2014) proposed. This research views FRM as a combination between defense, prevention, mitigation, preparation and recovery. NBS are only relevant with regard to flood defense, flood protection and flood mitigation. Here NBS can be implemented by themselves or they can be understood as an alternative or a complementary strategy to technical measures with the potential to bring multiple co-benefits.

### 2.2. Landscape barriers

Research on NBS for flood risk management points out that the implementation of NBS can be constrained with multiple barriers, but also enabled by certain opportunities (Kabisch et al., 2016) (Ershad Sarabi et al., 2019) (Raška et al., 2022) (Vojinovic et al., 2021). Barriers are defined as factors that hinder the uptake and implementation of NBS, and opportunities are the conditions that facilitate NBS. This study analyzes barriers and opportunities in two ways: governance and landscape.

Landscape challenges are the physical and spatial conditions of river catchments that determine the flood risks, but also the feasibility of implementing NBS. Limburg has a very different landscape than the rest of the Netherlands because of its hilly terrain and difference in runoff. Kok et al. (2023) show that in 2021 most damages were seen along smaller rivers such as the Geul where the terrain worsened the impacts of the flood. This shows that the physical structure of the landscape is important to understand the effectiveness of flood risk management in the form of NBS. The literature identifies three recurring landscape barriers that affect NBS implementation (Ershad Sarabi et al., 2019) (Raška et al., 2022) (Thaler et al., 2023) (Bohorquez et al., 2023) (Martin et al. 2025) (Kabisch et al., 2016).

Firstly, availability of land and spatial competition constrain the space that is available for NBS measures. Second, the dependence on private landownership complicates

implementation as it requires collaboration with more stakeholders. Finally, the physical landscape like steep slopes and narrow valleys form limitations around the feasibility of certain NBS measures. These barriers are summarized in table 1.

### 2.3. Governance barriers

In this research, governance challenges are central, because the uptake and implementation of NBS is dependent on how resources, knowledge, responsibilities and decision-making processes are organized. Flood risk management in Limburg involves multiple actors like provinces, water boards, municipalities, and local communities which makes it more likely for barriers to arise. The governance barriers that are described in this research are derived from recurring barriers that are describe in the literature on NBS. Looking at earlier studies (Kabisch et al., 2016) (Ershad Sarabi et al., 2019) (Raška et al., 2022) (Vojinovic et al., 2021) (Martin et al. 2025) (Cooper 2020) (Anderson & Renaud, 2021) (Han & Kuhlicke, 2019), this research distills 4 categories of governance barriers. Table 1 summarizes and explains all the specific barriers.

Institutional barriers cover obstacles related to the decision-making process of NBS. Within this category factors like risk aversion and path dependencies influence whether NBS are considered as an option. Additionally things like the lack of institutional support or institutional fragmentation form complications for coordination across sectors and stakeholders.

Financial barriers relate to funding frameworks and costs that determine the feasibility of NBS. These barriers are not only liked to short term investments, but also to the long term, where maintenance and monitoring costs come into play. In this way, these barriers give insights into the economic conditions that are needed for NBS development.

Social barriers reflect how stakeholders view NBS and how their different priorities can delay or hinder NBS implementation. This barrier category is not only about stakeholder attitudes towards NBS, but also how these stakeholders interact with each other.

Finally knowledge related barriers cover the availability, presence and use of knowledge about NBS. This is about evidence about NBS effectiveness, but also about broader knowledge of how NBS function in river systems.

### 2.4. Opportunities as a result of barriers

The literature on NBS gives a range of factors that enable their uptake and implementation. Common opportunities include collaboration between sectors and stakeholders, hybrid solutions which combine nature based and technical measures, studying, monitoring and sharing knowledge, evidence on performance and co-benefits, supportive policies and legal frameworks, and funding and financial tools (Kabisch et al. 2016) (Martin et al. 2025) ( Ershad Sarabi et al. 2019) (Cooper, 2020).

However, in this research, opportunities are not considered as separate variables alongside barriers, but as factors that are inherent to barriers. The previously identified landscape and governance barriers show reasons why NBS implementation is hard, but also give direction for the type of opportunities that are needed to make implementation easier.

By treating opportunities as emerging from barriers, this framework ties the two together which allows for a more coherent understanding of the uptake and implementation of NBS.

| Barrier category | Barrier | Description | Source |
|---|---|---|---|
| **Landscape** | Availability of land and spatial competition | NBS must coexist with farmland, residential areas and infrastructure. This limits the possibilities for NBS. | Kabisch et al. (2016), Thaler et al. (2023), Martin et al. (2025), Ershad Sarabi et al. (2019) |
| | Dependence on private landownership | In landscapes with fragmented private ownership it is difficult to acquire land for NBS development | Ershad Sarabi et al. (2019), Martin et al. (2025), Thaler et al. (2023), Raška et al., (2022) |
| | Topography | Steep slopes and narrow valleys make some NBS not feasible. | Raška et al., (2022), Bohorquez et al. (2023) |
| **Institutional** | Risk aversion | NBS can be seen as a risk to experiment with, so technical measures are preferred. | Kabish et al. (2016), Martin et al. (2025), Ershad Sarabi et al. (2019) |
| | Path dependency | The decision making process is based on technical measures, which makes it difficult to adopt new measures like NBS | Ershad Sarabi et al. (2019), Raška et al. (2022), Martin et al. (2025) |
| | Institutional fragmentation | Horizontal fragmentation or sectoral silos: limited cooperation between sectors.<br>Vertical fragmentation: limited cooperation between levels of government. | Ershad Sarabi et al. (2019), Vojinovic et al. (2021), Martin et al. (2025), Raška et al. (2022) |
| | Disconnection between the short and long term | Institutional preference to prioritize short term plans over long term goals such as climate adaptation which are needed for NBS. | Kabisch et al. (2016), Martin et al. (2025) |
| | Lack of institutional support | The absence of frameworks or instruments to implement NBS | Raška et al. (2022), Ershad Sarabi et al. (2019) |
| **Financial** | Lack of funding | Not enough money available to realise NBS projects | Ershad Sarabi et al. (2019), Martin et al. (2025), Kabisch et al. (2016), Cooper (2020) |
| | Lack of funding throughout the process | Costs for monitoring and maintaining NBS are often overlooked | Kabisch et al. (2016), Martin et al. (2025) |
| | Absence of short term gains | NBS often have no short-term economic and societal benefits and they are hard to quantify, making them less attractive. | Cooper (2020), Kabisch et al. (2016), Vojinovic et al. (2021) |
| | High and complex NBS costs | Long term maintenance and monitoring are sometimes more expensive and often more complex than technical measures. | Martin et al. (2025), Ershad Sarabi et al. (2019) |
| | Difficulty to value co-benefits | Valuation of NBS is hard and difficult. It is often underestimated. | Han & Kuhlicke, (2019), Kabisch et al. (2016) |
| **Social** | Stakeholder conflicts | Stakeholders have different priorities and different interests, this can create conflicts. NBS requires multi-level collaboration | Vojinovic et al. (2021), Martin et al. (2025) |
| | Stakeholder exclusion | Exclusion results in unequal participation and may cause resistance in the process | Raška et al. (2022), Ershad Sarabi et al. (2019), Han & Kuhlicke, (2019) |
| | Lack of awareness | Policy makers and professionals lack knowledge on what NBS are and how they can be implemented. | Kabisch et al. (2016), Raška et al. (2022) |
| | Negative NBS perception | Stakeholders can have a negative perception towards NBS and therefore prefer grey infrastructure. | Vojinovic et al. (2021), Han & Kuhlicke, (2019) |
| **Knowledge** | Lack of evidence about effectiveness of NBS | The effectiveness and co-benefits are not studied enough. This makes it harder to determine how well of a solution it is. | Raška et al. (2022), Ershad Sarabi et al. (2019), Martin et al. (2025) |
| | Lack of expertise and knowledge | Throughout the implementation stages of NBS there is a lack of expertise and knowledge. This includes the construction, the monitoring and the maintenance. | Martin et al. (2025), Ershad Sarabi et al. (2019) |
| | Lack of long-term monitoring | Even when NBS are implemented successfully, long-term monitoring often does not occur. | Han & Kuhlicke, (2019), Ershad Sarabi et al. (2019), Martin et al. (2025) |
| | Science-practice gap | There is a disconnection between academic research and local implementation, making it harder to improve NBS implementation. | Anderson & Renaud, (2021), Martin et al. (2025) |

*Table 1: All barriers in their categories with explanation and sources*

## 2.5. Conceptual model

When looking at the conceptual model (Figure 2) it becomes clear that this research combines landscape and governance barriers and opportunities to construct a framework for analysing the uptake and implementation of NBS in small rivers. Following this rhetoric, this study conceptualizes the implementation of NBS in small rivers in Limburg as the outcome of these two challenges. This double perspective will lead to a more holistic understanding of the constraints for NBS in small river flood risk management, but also makes potential opportunities visible.

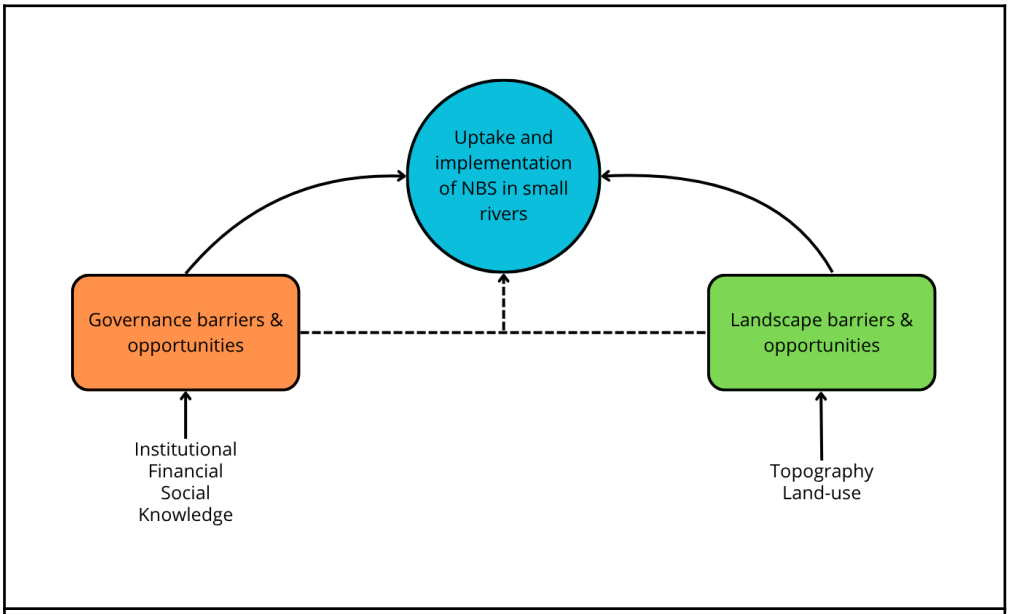


**Figure 2**: Conceptual model with governance and landscape challenges acting together to influence the uptake and implementation of NBS in small rivers in Limburg.

# 3. Methodology

This research uses multiple methods to gain a complete view of how governance barriers and landscape barriers influence the uptake and implementation of NBS in small rivers in Limburg and what opportunities arise from them.

### 3.1. Case study selection

This research uses a case study approach, with a focus on small rivers the Dutch province of Limburg. This case was selected as a relevant and suitable case because of the amount of small rivers it contains, and that they caused serious damage during the floods in 2021 (Kok et al. 2023). This damage occurred along small rivers such as the Geul, Geleenbeek and the Roer (Figure 3).
Limburg presents and especially interesting case because its unique hilly terrain and a high diversity in land uses within the small river catchments. This makes it interesting to look into the feasibility of NBS here.

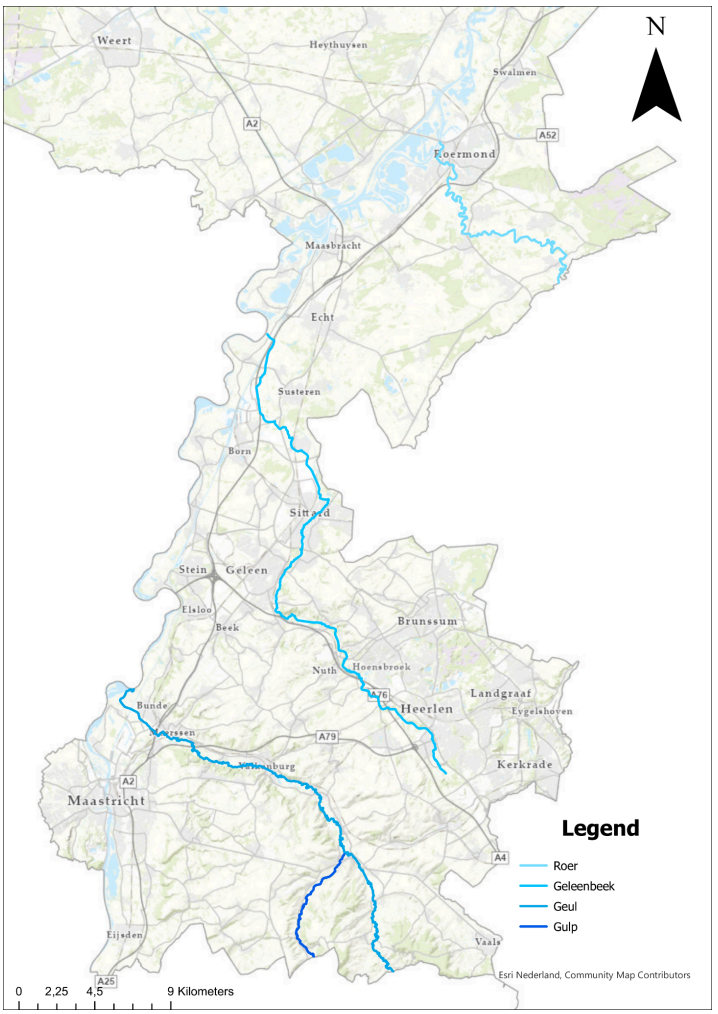


**Figure 3**: Map of limburg, with its small rivers

### 3.2. Data collection

This research uses three different methods to research the governance and landscape barriers that influence the uptake and implementation if NBS in small rivers in Limburg. The data collection consists of (I) Semi-structured expert interviews (II) Grey literature analysis, complemented by (III) GIS-mapping.

Primary data was collected trough semi-structured interviews with experts that are involved in the flood risk management and NBS projects in the province of Limburg. An interview guide was constructed for this (Appendix A). Initially, participants were selected based on their knowledge and involvement around FRM. However, because of the scope of this research, snowball sampling was used to gain access to more respondents. In total, 6 interviews were conducted (Table 2) where key themes where discussed, but there was also left room for different themes to emerge.

| Document | Interview number | Organisation/Level | Role |
|---|---|---|---|
| D8 | 1 | Waterschap | Strategic function |
| D2 | 2 | Water in balans | Project leader rural area |
| D3 | 3 | Waterveiligheid en Ruimte Limburg (WRL) | Project leader Nature Based Solutions |
| D4, 5, 6, 7* | 4 | NGO | Team drielandenpark - ARK rewilding |
| D25 | 5 | NGO | Program manager Natuurkracht South-Limburg |
| D26 | 6 | Limburgs Particulier Grondbezit (LPG) | LPG |

***Table 2**: All expert interviews conducted, with interview number, organisation at which the respondent is active, and their role*

On average, the interviews 45 minutes and all of them where audio recorded in Dutch in order to ensure they could express their answers naturally. The respondents were asked to sign a consent form (Appendix B) and permission was asked for the use of quotes.

The second of this research will use is the analysis of grey literature. This includes the analysis of policy documents, but also reports, evaluations, and project description of running and completed NBS projects in Limburg. A benefit from using policy documents as well as other grey literature is there is space to not just look at formal policy framing but also practical project experience. The collected data is showed in table 3. In appendix C the table is showed in more detail. The documents were selected using the following criteria: (i) the documents concern flood risk management or water management that is in the province of Limburg. (ii) The documents have to refer to NBS or similar approaches like “working with nature or water and bodem sturend”. (iii) The documents have to contain information about governance, landscape conditions, or the implementation of a project. (iv) The documents have to be from 2018 to 2025, to make sure they are relevant when placed in the 2021 flood policy context.

| Type of document | Amount of documents |
|---|---|
| Policy document | 3 |
| Evaluation | 3 |
| Legislation | 1 |
| Report | 2 |
| News/media sources | 7 |

**Table 3**: Documents used for grey literature analysis

For the landscape analysis GIS mapping will be used. The GIS analysis will be kept deliberately simple. Rather than modeling hydrological processes, this analysis will focus on mapping land use, topography and the main river catchments in Limburg (Geul, Gulp, Geleenbeek, Roer). The end result will be a spatial overview of where there are landscape conditions that may constrain NBS, or where there are possibilities for NBS. It will serve as a visual complementation to the findings from the interviews and the grey literature analysis. The maps were constructed using publicly available data from PDOK and arcgis online.

These three methods compliment each other. The grey literature analysis identifies how NBS is intended and where governance challenges arise, the interviews give a deeper understanding of these governance challenges and also reveal landscape challenges (Figure 4). Lastly the GIS-based landscape analysis provides a spatial perspective of where the earlier identified challenges can be compared to. Literature, professional experiences and spatial evidence are combined to provide a comprehensive understanding of how governance and landscape factors combined influence NBS of small rivers in Limburg.

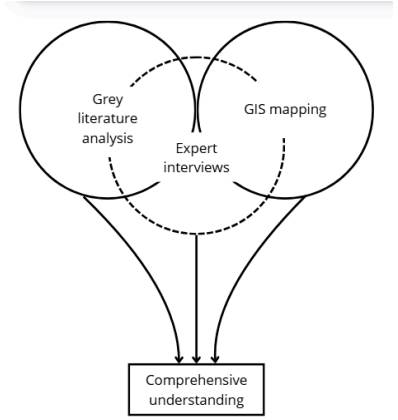


**Figure 4**: Methods diagram showing how three different analysis work together to gain a comprehensive understanding.

### 3.3. Data analysis

The collected and transcribed interviews as well as the grey literature were analysed using coding in Atlas.ti.
For both types of data, the same coding framework was used to make sure patterns could be identified across the different types of data.
The coding framework is based on the barriers identified in the theoretical framework. Separate code groups were formed using the categories from the theoretical framework and each barrier was converted to a code. These form the most important part of the analysis. Alongside the barriers, codes were also made for opportunities as well as contextual codes like types of NBS, but also different stakeholders and NBS definitions. Additionally during the coding process there was also paid attention to the emergence of inductive codes. These were added to the codebook when they appeared multiple times throughout different data sources. The combination of deductive and inductive coding made for the results to be grounded in the theory, but also open to context-specific factors in Limburg. This resulted in a total of 38 different codes. The full coding scheme including inductive insights can be found in Appendix D.
The intention of this analysis is to find out which codes and code groups emerge most frequently. This results in a holistic insight in which barriers and opportunities influence the uptake and implementation of NBS is small rivers in Limburg

# 4. Results

This section contains the results of the empirical analysis of governance and landscape barriers and opportunities which influence the uptake and implementation of NBS in the flood risk management of small rivers in Limburg.
The analysis was defined in the theoretical framework, but multiple other inductive themes emerged in the data. These will be discussed in the relevant sections.
In this section interpretation is kept to a minimum. The focus here, lies on describing patterns and themes that come directly from the data.

### 4.1. Types of NBS

Across expert interviews, NBS do not have a clear definition. They are defined in broad and practice oriented terms. Co-benefits are a substantial part of the EU-definition of the concept, but they are rarely mentioned in the data. In the document analysis NBS are also not explicitly defined.
Several respondents pointed out that the core criterion of NBS is “working with nature” or “embracing nature as an ally” (Interview 5, Natuurkracht). Descriptions of NBS are mostly linked to landscape and rural contexts like one interviewee described; “*It's mainly about how you can use landscape,nature, and landscape elements in a rural area to limit risks or retain water*” (Interview 2, Water in Balans).
Additionally it is also mentioned by interviewees that measures are very context specific, and that they can vary under different circumstances.
The dependence on context becomes visible in examples like graften, wich are terraced edges with vegetation that delay runoff and retain water. This measure is only possible on hillsides and are therefore specific to the hilly landscape of South-Limburg (Figure 5).

**Figure 5**: Graften in southern Limburg
*Source: Waterschap limburg, 2019*

Despite a clear definition being absent, the documents and interviews name a number of concrete NBS measures that are applied in the context of small rivers in Limburg. Measures that are frequently mentioned are re-meandering and raising small river beds to give more space for water and delay runoff. Also, measures aimed at increasing the sponge function of the landscape like the conversion of farmland to forest, but also letting big grazers onto grassland. The grazers make indents into the grassland, wich increases the relief of the landscape making it possible to retain more water. Finally, the restoration of graften-systems is mentioned multiple times as a measure that helps mitigate flood risks.
All things considered, the findings suggest that NBS in Limburg are understood not as a certain set of measures, but more as an approach that is suited for local landscape factors. The types of NBS are context specific and differ between areas depending on factors such as topography and land use.

| Barrier category | Barrier | Description barrier in Limburg | Frequency Total: 264 |
|---|---|---|---|
| **Landscape** | Availability of land and spatial competition | In limburg there is limited land available for the implementation of NBS. | 34 |
| | Dependence on private landownership | Private landownership along small rivers make NBS implementation dependent on other parties, mostly farmers | 11 |
| | Topography | In Limburg, topography is not identified as a direct barrier to NBS. | 8 |
| **Institutional** | Risk aversion | Risk aversion leads to technical measures over NBS. Respondents link this to the uncertainty about the effectiveness of NBS. | 3 |
| | Path dependency | Technical approaches that are in place and evaluation criteria make conventional flood risk measures more suitable. This limits the consideration of NBS in Limburg. | 9 |
| | Institutional fragmentation | In Limburg, institutional fragmentation is visible because of the many actors and governance layers, which results in overlapping responsibilities and complex coordination, | 15 |
| | Disconnection between the short and long term | This barrier is not mentioned often in the data. When it occurs it relates to tensions between short term political priorities and long term goals for implementing NBS | 4 |
| | Lack of institutional support | Lack of institutional support in Limburg becomes visible in limited instruments, unclear responsibilities and insufficient implementation power. | 9 |
| Inductive barrier | Cross-border governance complexities | Different governments and policy priorities across the Belgian and German border makes NBS implementation dependent on decisions made abroad. | 9 |
| Inductive barrier | Political volatility and politicisation | Politicization and changing priorities affect decision-making and create inconsistent NBS support. | 10 |
| **Financial** | Lack of funding | Not enough money available to realise NBS projects | 6 |
| | Lack of funding throughout the process | Long-term funding for maintenance and monitoring lack, and create gaps throughout the NBS processes in Limburg | 5 |
| | Absence of short term gains | In Limburg limited short-term returns make NBS unattractive for landowners with productive agricultural land. | 6 |
| | High and complex NBS costs | Expensive land, research costs and complex land acquisition processes lead to high and complex costs, which hinder the implementation of NBS in Limburg. | 14 |
| | Difficulty to value co-benefits | It is hard to quantify and financially value NBS co-benefits. This limits their integration into plans made for Limburg | 10 |
| **Social** | Stakeholder conflicts | In Limburg, there are competing interests among landowners, farmers, residents and authorities which leads to resistance and delay in the implementation of NBS | 20 |
| | Stakeholder exclusion | Late or limited or no involvement of stakeholders in NBS projects leads to a lack of trust and eventually resistance in Limburg | 8 |
| | Lack of awareness | Awareness of flood risks in Limburg and NBS is still limited and uneven. | 8 |
| | Negative NBS perception | NBS are sometimes seen as less reliable and less effective comparted to technical measures. This leads to reduced support for NBS in Limburg. | 8 |
| **Knowledge & capacity** | Lack of evidence about effectiveness of NBS | There is still limited evidence about how effective NBS are in Limburg. Additionally their impact is hart to quantify which reduces confidence in broad NBS implementation. | 19 |
| | Lack of expertise and knowledge | Limited availability of NBS specialized expertise and NBS models constrain the implementation of NBS. | 11 |
| | Lack of long-term monitoring | In Limburg there is limited long-term monitoring on the effects of NBS. This limits the potential to learn from projects. | 4 |
| | Science-practice gap | The research that is being done does not align with practical NBS implementation needs in Limburg. | 6 |
| Inductive barrier | Limited organisational capacity | Shortages in personnel and limited organisational capacity delay implementation and long-term management of NBS projects in Limburg | 9 |
| Inductive barrier | Lack of decisiveness and implementation power | There are plans for NBS in Limburg, but they are not sufficiently put into action, resulting into delayed and limited implementation in Limburg | 13 |

**Table 4**: summary from barriers taken from both expert interviews and documents. Each description contains the recurring themes that are relevant for the Limburg context, rather than individual statements or quotes.

### 4.2. Landscape barriers

The analysis shows that landscape barriers play a significant role in the uptake and implementation of NBS in the flood risk management in small rivers in Limburg. Among the landscape barriers identified from the literature, availability of land and spatial competition is the most dominant barrier in Limburg followed by dependence on private landownership. Topography however is not described as a direct barrier to NBS implementation in Limburg. Availability of land and spatial competition is the most frequent landscape barrier across both interviews and policy documents (Table 4). Respondents repeatedly made statements about the lack of land to implement NBS. For example; *"It's just the land positions that make it difficult to roll it out on a large scale" (Interview 3, WRL).* This pattern is also visible in policy documents; "*The implementation of stream restoration projects by the Limburg Water Board is lagging behind expectations, mainly due to difficult land acquisition*" (Provincie Limburg, 2022. D11).This pattern is also visible in the spatial distribution of land use in Limburg. As shown in figure 6, large parts of small river catchments are dominated by agriculture, which results in competition between flood risk management goals and existing land-use.

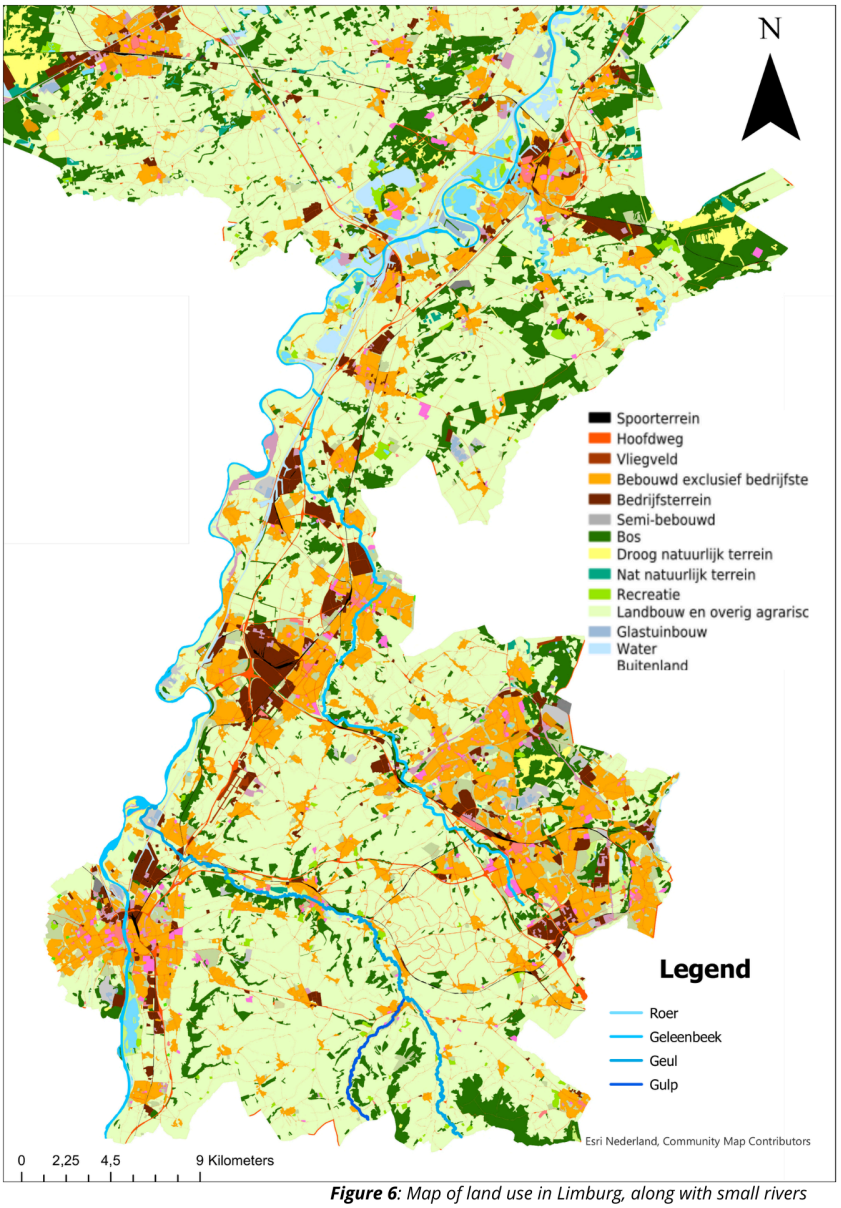


***Figure 6**: Map of land use in Limburg, along with small rivers*

Dependence on private landownership relates to the previous barrier. Interviewees pointed out that to implement NBS on a large scale they are very dependent on private landowners, especially because of the fact there are too little coercive instruments in place. "*We also have no binding instruments to oblige landowners to do things, so we are very dependent on other parties*" (Interview 3, WRL). This makes the implementation of NBS more complex as voluntary cooperation, land acquisition, or compensations are necessary.

Topography however, was mentioned in the data, but not as a barrier to the implementation

of NBS. Respondents stated that the hilly terrain in Limburg intensified runoff and increased flood risks in small rivers, making the problem more urgent and complex. Steep slopes and valleys do shape the type of measures that are possible in Limburg. The data does not indicate that topography in itself limits the implementation of NBS. The data does show that the landscape makes the problem of flooding more urgent, as runoff speed is increased. Overall, the analysis shows that landscape barriers in Limburg are mostly related to spatial constrains and private landownership. Topographical factors shape the context and urgency of FRM but are not a limitation in the feasibility of NBS.

### 4.3. Governance barriers

During the coding process, multiple inductive barriers came up along with the deductive barriers from the theoretical framework. These were integrated into the results (Table 4). Overall, institutional barriers were the most dominant, and after that knowledge and capacity barriers. Less frequently mentioned were economic and social barriers.

*Institutional barriers*: The most dominant barrier in this category is institutional fragmentation which refers to coordination between sectors and stakeholders. In limburg's river management are a lot of stakeholders involved with different agendas and projects that overlap. Documents described that many partnerships and projects can lead to overcrowding and unclear responsibilities wich causes delays. After institutional fragmentation political volatility and politicization came up as a dominant institutional barrier and is an inductive insight. This was most visible in the expert interviews where respondents described how there is a need for a different direction in politics, and that the politicization of water management made for complex situations. "*Water has become increasingly political, and therefore simply less reliable*" (Interview 1, waterschap). This politicization influences the continuity of water policy, and forms a barrier for consistent political support of NBS. The interviews refer to situations that have to do with land acquisition, where proposed measures are being reconsidered or delayed by a change in political priorities. Path dependency also came up as a relevant barrier. Documents and respondents stated that NBS is a relatively new concept and policy and legislation is not fully adjusted to facilitate NBS.

*Economic barriers* were mentioned mostly in the expert interviews and less in the policy documents. The most prominent economic barrier is related to the high and complex costs of NBS. Respondents described that these costs are not due to construction, but are related to the high costs of land acquisition and research before implementing NBS. The findings from Limburg reflect that the costs of NBS are closely related to the land price. The analysis also points out that NBS are less attractive because it is hard to put a value on its effects. For example, if a farmer has to exchange productive land for an NBS project, he will suffer financially and experience no short-term benefits.

*Social barriers* is one of the least mentioned categories, and is mostly related to stakeholder dynamics. Respondents describe tensions between landowners, farmers and governments especially when NBS requires land-use change. Stakeholder conflicts delay, or lead to a discontinuation of NBS. Additionally respondents referred to a negative perception of NBS especially on its effects.

Next to institutional barriers, knowledge related barriers are one of the most significant governance barriers identified in the analysis. The lack of evidence about NBS effectiveness was the most frequently mentioned in this category. Respondents mentioned that in policy there is often a standard or an amount of water that has to be retained, and that with NBS it is unclear what kind of impact you make on this. This makes NBS less attractive as opposed to technical measures where you can calculate exactly how much water is retained. The

analysis also points out that there is a general lack of expertise and knowledge about NBS and its implementation. However, respondents state that there is a lot of research being done, but it does not apply to specific projects, which creates a science-practice gap. Deductive insights in this category are that there is a lack of decisiveness and implementation power. Meaning, ambitions for NBS are there, but actual choices that need to be made for implementation stay behind.

### 4.4. Opportunities

In the coding process, opportunities for the uptake and implementation of NBS in small rivers in Limburg were identified alongside with the barriers. The findings are not presented as a separate category, because they are inherently linked to the barriers described in the previous sections.

Three dominant opportunities emerged from the analysis: collaboration across sectors and stakeholders, Studying monitoring and sharing knowledge, and the development of supportive policies and legal frameworks.

In previous sections it is described that institutional fragmentation and stakeholder conflicts form major barriers for the implementation of NBS in small rivers in Limburg. Simultaneously, respondents and documents indicate that collaboration across sectors and stakeholders is an important or essential opportunity to overcome these barriers. This is also reflected in policy documents, for example "*Partnership and cooperation are essential for the realisation of the WRL task*" (Programma Waterhveiligheid & Ruimte Limburg, 2025. D10).

As discussed in section 4.3, the lack of evidence about the effectiveness of NBS in small rivers is a major barrier in Limburg. Respondents indicate that quantifiable and clear outcomes are needed in the decision making process for NBS. One respondent points out "*Until we can make all those values transparent, there's no room in that system for large-scale application of nature-based solutions*" (Interview 5, Natuurkracht). This shows that this knowledge gap creates an opportunity for studying, monitoring and sharing knowledge.

Lastly, as discussed, the lack of institutional support and constrains related to the availability of land are important barriers to the implementation of NBS in small rivers Limburg. The analysis points out that existing policy instruments are not sufficient to steer land use or implement NBS on a large scale. "*To tackle the problem at the root, you will have to redesign your entire landscape and the water board has no instruments for this at all*" (Interview 3, WRL). This limitation creates opportunities for the development of supportive policies and legal frameworks that make NBS implementation at a bigger scale possible. These policies are particularly relevant in Limburg, as the competition for land is high.

# 5. Discussion

This research analysed which landscape and governance barriers and opportunities influence the uptake and implementation of NBS in the flood risk management of small rivers in Limburg, and how these two interact. Both landscape and governance barriers influence NBS implementation, but governance barriers have a bigger role in determining if NBS are actually realised. Landscape conditions give the physical boundaries for the possibilities of NBS and governance factors shape how these boundaries are managed.

Governance barriers were most present in relation to institutional fragmentation, high and complex costs, and lack of evidence about NBS effectiveness but also stakeholder conflicts. These barriers do not necessarily make NBS impossible, but they limit their operationalisation and make it hard to implement them systematically. A result of this is that NBS are not integrated into broader, provincial FRM implementation strategies in practice. NBS are included in new policies, but due to a lack of supportive frameworks and instruments, they can't be implemented effectively.

Landscape barriers, but mostly the availability of land were also identified as relevant barriers to NBS. However, the findings indicate that these are not fixed barriers, but that they only are constraining under specific governance conditions. This suggests the limited uptake of NBS in small rivers can not only be explained by the landscape conditions, but it has to be understood as a result of how governance structures interact with them. Current policies appear under-equipped to deal with this interaction and treat landscape conditions - largely the availability of land- as fixed barriers rather than as conditions that need adapted, context-specific and collaborative governance responses. Additionally, the development of such policies and approaches is discouraged by the lack of evidence about NBS effectiveness in small rivers. Without fully understanding of how NBS measures contribute to the reduction of flood risks, it remains unattractive to develop policies where NBS can be integrated in a wider strategy.

The findings of this research are mostly in line with existing literature on NBS, but it adds a context-specific nuance with regard to small rivers and the Limburg case. First of all, with regard to NBS in general, Sowińska-Świerkosz & García (2022) state that NBS definitions are general and blurry. This research confirms this and shows that a clear definition is also absent in Limburg. Secondly the importance of land availability as a significant barrier is in line with other studies, which show that NBS measures need more space compared to technical measures (Turkelboom et al., 2021)(Bogdzevič, 2023). The case of Limburg supports this especially in relation to small river landscapes on hilly terrain with fragmented ownership. Linked to this are economic factors. Other studies suggest that in general NBS are relatively cheaper than technical measures especially when co-benefits are taken into account (Turkelboom et al., 2021) (Chiu et al., 2021). This study does not contradict this, but adds a nuance by accounting for the price of land in the context of small rivers in Limburg. Last of all, the findings are in line with other research that show a lack of knowledge and lack of evidence about effectiveness of NBS. Keech et al. (2023) and Christopher er al. (2024) suggest that this lack of understanding is a large barrier to a wider uptake of NBS. This analysis strengthens this argument and shows that knowledge gap about effectiveness forms also a barrier in the context of small rivers in Limburg.

There are a few lessons that can be learned of Limburg. The case of limburg shows that reducing institutional fragmentation is important for the uptake and implementation of NBS. The program Waterveiligheid en Ruimte Limburg (WRL) is a promising initiative where the Limburg's municipalities, the province, the waterboard and the state join forces to reduce

flood risks. The fact that this program has been developed suggests that a context-specific area governance approach is needed to get NBS on the agenda. Limburg also showcases that this multi layer collaboration does not automatically lead to more NBS. For that more supportive policies and legal frameworks are needed.
Additionally the Limburg case suggests that a focus on acquiring land from private landowners only partially contributes to the implementation of NBS in small rivers. Land acquisition can certainly be a solution for individual projects, but this strategy to be less effective when NBS is considered in broader strategies. In practice this leads to individual plots of land being available for NBS, but where scalability and long term monitoring and management are not sufficient.

# 6. Conclusion

This research was aimed examining how landscape and governance barriers and opportunities influence the uptake and implementation of NBS in the FRM of small rivers in Limburg. The findings show that governance barriers play a bigger role than landscape barriers in the process of NBS implementation. The major barriers that where identified are institutional fragmentation, stakeholder conflicts, high and complex costs, lack of evidence about effectiveness and availability of land. Additionally, the results show that landscape and governance barriers should not be considered as separate factors. The lack of available land can be treated by making supportive policies and collaboration across sectors and stakeholders. In order to make these supportive policies, more evidence and knowledge of the effectiveness of NBS in FRM is needed.

### 6.1. Limitations

It is important to recognize that this study has a few limitations. Firstly, this research is based on a relatively small number of documents and interviews. In the data collection process, snowball sampling was used to get access to expert interviews. This means that not all stakeholders involved in NBS process were evenly represented. Even though efforts were made gain an understanding of what NBS entail, it remains a broad concept, which may have influenced how respondents interpreted NBS in small rivers in Limburg. Lastly, Limburg is a very different province than the rest of the Netherlands with regard FRM problems, but also landscape. This limits the extent to which the findings of this study can be generalised.

### 6.2. Policy recommendations and future research

With regard to the findings of this study, policy should focus on stronger governance conditions under which NBS can be implemented. This can include incentives to improve collaboration between sectors and stakeholders and developing financial instruments to make implementation, long term monitoring and research easier. More research should be done on how effective NBS is, with the goal of ensuring NBS can be taken up better in policies. Additionally, future research could add on this study by including more perspectives of local farmers and landowners and local communities, or focusing on a smaller scale, specific catchment to gain more precise insights.

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Fig 5: Waterschap Limburg. (2019). *Graften in Limburg* [Photograph]. https://www.waterschaplimburg.nl/publish/pages/4565/940px/graften.jpg

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# Appendix A: Document analysis

This appendix contains a table with all documents that where coded in the document analysis.

| Document | Type | Title | Year | Level | Main focus | Found at |
|---|---|---|---|---|---|---|
| D9 | Policy document | *Opbouwplan programma WRL. Gericht aan de slag* | 2023 | Provincial | Governance structure and approach in small rivers in Limburg. | https://wachtnietopwater.nl/wat-doet-de-overheid/documenten/ |
| D10 | Evaluation | *Voortgangsrapportage WRL – januari t/m juni 2025* | 2025 | Provincial | Describes governance progress watermanagement Limburg | https://wachtnietopwater.nl/wat-doet-de-overheid/documenten/ |
| D11 | Evaluation | *Voortgangsrapportage Provinciaal Waterprogramma 2022–2027 (eerst tweejaarlijkse voortgangsrapportage en evaluatie 2022–2023)* | 2023 | Provincial | Overarching provincial water management strategy | https://www.limburg.nl/publish/pages/979/voortgangsrapportageprovinciaalwaterprogramma2022def.pdf |
| D12 | Legislation | *Omgevingsverordening Limburg* | 2025 | Provincial | Legal rules on the water system and nature in Limburg | https://lokaleregelgeving.overheid.nl/CVDR705183/2#chp_14 |
| D13 | Policy document | *Provinciaal waterprogramma 2022-2027* | 2022 | Provincial | Overarching provincial watermanagement strategy | https://www.limburg.nl/publish/pages/979/provinciaal_waterprogramma_2022-2027.pdf |
| D14 | Evaluation | *Leerevaluatie hoogwater Maas en Roer (veiligheidsregio Limburg-Noord)* | 2021 | Regional | Crisis evaluation of 2021 | https://www.vrln.nl/sites/vrln/files/2022-10/Leerevaluatie_Hoogwater_Maas_en_Roer_VR__Limburg_Noord_2021_rapportage.pdf |
| D15 | Report | *Juli 2021 overstroming en wateroverlast Zuid-Limburg. Eerste bevindingen voor Valkenburg, Geulmonding, Roermonding en Eygelshoven.* | 2022 | Regional | Technical report on the 2021 flood and explores possible measures. | https://www.deltares.nl/expertise/publicaties/juli-2021-overstroming-en-wateroverlast-in-zuid-limburg-eerste-bevindingen-voor-valkenburg-geulmonding-roermonding-en-eygelshoven |

| | | | | | | |
|---|---|---|---|---|---|---|
| D16 | Policy document | *Visie Beekdalontwikkeling in Limburg* | 2018 | Waterschap | Vision on nature based development in Limburg | https://www.waterschaplimburg.nl/publish/pages/4538/visie_beekdalontwikkeling.pdf |
| D17 | Report | *HNS Geuldal-Rapport definitief* | 2023 | Regional | Landscape and ecological report of Geuldal | https://www.nmflimburg.nl/wp-content/uploads/sites/12/2023/11/Water-vasthouden-en-vertragen-in-het-Geuldal-rapport.pdf |
| D18 | News/media source | *Dit leren de overstromingen in Limburg ons* | 2025 | National | Scientific insights of 2021 floods | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:6G7K-R903-RWWG-233P-00000-00&context=1519360 |
| D19 | News/media source | *Bodem in het Geuldal niet snel verzadigd* | 2022 | Regional | Sponge capacity of Geuldal soil. | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:65RG-K8K1-JCWP-90GT-00000-00&context=1519360 |
| D20 | News/media source | *Beter opvang regenwater rond Gulp en Geul* | 2023 | Regional | Describes NBS projects in Limburg | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:68S5-11H1-F0BS-12D7-00000-00&context=1519360 |
| D21 | News/media source | *Onenigheid over begroeiing langs de Maas* | 2022 | Regional | Governance conflict RWS and Natuurmonumenten | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:65WY-GJ11-JCWP-906T-00000-00&context=1519360 |
| D22 | News/media source | *Nathalie onderzoekt hoe limburg zich kan wapenen tegen een nieuw 'waterbom'* | 2023 | Regional | Interview with Deltares researcher | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:6967-HWD1-JCWP-90YW-00000-00&contex |

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|---|---|---|---|---|---|---|
| | | | | | | t=1519360 |
| D23 | News/media source | *Hoe voorkom je wateroverlast na een plensbui? De reis van een regendruppel door het Geuldal* | 2024 | Regional | Explains how NBS work in the Geuldal | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:6CMY-RBD1-JBHV-K1CJ-00000-00&context=1519360 |
| D24 | News/media source | *Het landschap als klimaatbuffer tegen overstromingen* | 2022 | Regional | Explores NBS as a strategy in the Geuldal | https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:66R0-TP31-JBKF-M4G5-00000-00&context=1519360 |

# Appendix B: Coding scheme