FLOOD RESILIENCE OF COMMUNITIES ALONG THE SALZACH RIVER, AUSTRIA

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Abstract

Floods are a reoccurring phenomenon in the Alpine region of Austria. One region which had many historical flood events is the district of Zell am See. The Salzach River, which originates from the mountains, is repeatedly flooding fields and communities along its banks. After a particularly big flood in 2005 the communities constructed a flood protection system. However, the frequency and intensity of floods in recent years requires a continuous adaptation to floods. The need for this was shown during the flood in 2021, which brought the flood infrastructure to the limits of its capacity. The repetitive flooding created resilience amongst the communities to protect themselves and their ability to develop.

In this thesis, the level of resilience of the communities along the Salzach River was assessed based on the sources of resilience identified within the Zurich Flood Resilience Measurement Framework. The assessment is based on four major capitals, which are necessary for the community's resilience: natural, physical, financial, and social capital. Interviews with local representatives of both governmental and nongovernmental actors were conducted and relevant documents were obtained to collect the necessary data.

The results show a high level of community resilience, for which the financial, social and physical capital are the main contributors. The natural capital, with the forests contributing as a natural form of flood prevention system, also contribute to the resilience. Nevertheless, this aspect leaves the most room, for further improvement. However, even though the community resilience is sufficient, the expected climatic change requires continuous improvements on the flood coping infrastructure. This would be in line with the efforts, such as infrastructural improvements and community initiatives for better flood prevention, which the communities have shown in the past.

Building on the findings of this research, two avenues are identified for future research. First, the contribution of the household level to the communities' resilience can be investigated in future research. Second, the role of climate change on floods in the alpine region offer an additional topic of further research.

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List of Abbreviations

DRM	Disaster Risk Management
HQ 100	A flood event that statistically occurs every 100 years
HQ 300	A flood event that statistically occurs every 300 years
IPCC	Intergovernmental Panel on Climate Change
PCA	Principal Component Analysis
UN	United Nations
4/5 Cs	4/5 Capitals
4Rs	Robustness, Redundancy, Resourcefulness, and Rapidity

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1. Introduction

1.1. Background

The Alps are the highest mountains in Central and Southern Europe. Their natural beauty makes them popular amongst tourists. This beauty can become dangerous if heavy precipitation and storms turn the mountain slopes into danger zones. Its geographical setting in combination with its formation makes the Alpine Region prone to flooding. In contrast to flatter regions in lower altitudes, floods can also be caused by rapid snowmelt or melting of glaciers and damming of rivers caused by avalanches or landslides (Papathoma-Köhle et al., 2010). A particularly vulnerable zone includes the catchments between an altitude of 1.000 and 2.000 meters. There are two main reasons for this vulnerability. First, the snow is sensitive to temperature changes and higher precipitation in comparison to lower laying areas (Weingartner et al., 2003). Second, with increasing altitude, the thickness of the soil layer and the density of vegetation is decreasing, which results in a decreased capacity to hold water. Regardless of the altitude, are the angle of the slope and the either windward or leeward position of the slope factors which can increase the flood risk for valleys. The higher the degree of the slope, the lower the retention capacity since gravity is drawing less water into the soil (Weingartner et al., 2003).

Environmental changes of the past decades, in both the natural and build environment, contributed highly to an increased flood risk in the alpine region. A change in land use in catchment in as well as modification of flow regimes directly impacted the river flow, such as "magnitude, frequency, duration, timing, and rate of change" (Stoffel et al., 2016, p.3). Other hard measures, such as river channelisation, reduced the ability of the water body and flood plains to store water, and the risk of floods in the downstream area increased.

As a result of climate change, the frequency and intensity of floods in general have increased. According to the latest IPCC report, it is expected that a larger area will be affected by an increase in river floods than the area with a decrease in river floods (Pörtner et al., 2022). Taking this into account, more than the current 34.4 million people (Visual Capitalist, 2022) will be affected by floods in the future per year. The IPCC report specifically warns that "cryosphere related changes in floods, landslides and water availability have the potential to lead to severe consequences for people, infrastructure and the economy in most mountain regions" (Pörtner et al., 2022, p.61).

The district Zell am See, which is situated in the State of Salzburg, is surrounded by alpine peaks up to 3,000 meters. Historically is the district frequently confronted with rising water levels several times a year. However, over the past 25 years, the frequency of floods with seriously damaging dimensions increased. A particularly bad flood in 2005 initiated the need for a more active flood protection. The floods following after the instalment of the flood protection infrastructure confirmed the deed for such structures.

1.2. Problem Statement

The communities along the Salzach are very much used to the seasonal floods since it is a reoccurring event since centuries. However, within this century alone two floods with the statistical likelihood of reoccurring once in 100 years happened and then in 2021, a flood with is historically happening every 300 years hit the communities. This change in more frequent extreme events is attributed to climate change and will most likely keep impacting the communities in the future decades. What makes this case to exceptional is the combination of the change in weather pattern combines with the geographical location of the communities. Situated in a valley in the Austrian alps with peaks up to 3,000 meters to the south of it, in an event of extreme precipitation the water falling in the mountains will gather either thorough surface water runoff or mountain streams in the Salzach. This can cause a dangerously quick increase of water levels. Additionally, the mountains in the south with first the Granatspitz Gruppe and then the Hohe Tauern are substantially higher than the ones in the ones in the north. If the wind is coming from the north or especially the northwest, rain clouds are caught and can cause heavy rainfall.

It lays in the nature of valleys the space for settlements is limited, which results in increasing damaged property if settlements expand in size since the space suitable for building is limited to the bottom of the valley with is automatically in close proximity to the river. This is also the case for the communities in along the Salzach River.

As previously mentioned, a change in weather patterns is expected due to climate change, which can result in more frequent and extensive flooding. Therefore, the communities along the Salzach River should be resilient to flooding. An assessment of the current level of resilience can provide empirical insights into possible points of improvement. Subsequently, the topic of the research is the assessment of the resilience of municipalities in the regional district of Zell am See.

1.3. Research Objectives

The objective of this research is to gain a better understanding on the resilience of the communities along the Salzach. The focus is on improving the flood resilience of the communities. In order to acquire a better understanding of the local situation, the current and expected impacts of flood on the community was identified. Following the investigation of the existing and future impacts, the natural, physical, social and financial factors which influence the state and level of resilience were investigated. This includes both positive and negative influence. Finally, the resilience of the communities as a whole were assessed. To assess the degree of resilience, all relevant influencing factors were applied, based on a set of indicators. This set of indicators are pre formulated by the community flood resilience measurement tool of Keating et al. (2017). Therefore, both weak points and sources for the current resilience level have been identified.

1.4. Research Questions

In order to achieve the research objectives, the main concerns were formulated into research question. The primary aim for this research is addressed through the main research question. The three sup-questions further investigate the aspects that are essential for answering the main research question.

Main research question of the thesis is formulated as follows:

> **How should the flood resilience of communities along the Salzach River be improved?**

To answer the main research question, the following three sub-questions are answered:

1. What are the current and expected impacts of floods on the communities along the Salzach River?
2. Which natural, physical, social and financial factors influence the flood resilience of the communities along the Salzach River?
3. How resilient are communities along the Salzach River to flooding?

1.5. Thesis Outline

The reminder of the thesis consist of five chapters. In chapter 2, the theoretical framework is presented, which forms the theoretical foundation on which the thesis is based. Following this is chapter 3, in which the methodology of this research is explained. The results regarding each research question are elaborated on in chapter 4. Finally, in chapter 5, the findings of the thesis are discussed and put into context with other research findings.

2. Theoretical Framework

The framework of this research includes concepts which are already developed in previous studies, and which are essential for the further understanding of the framework. Those two being the concepts of resilience and flood resilience, are elaborated in the first two sections. Additionally, the community flood resilience framework of Keating et al (2017) is introduced from which the framework for this research was developed. The development of the framework that forms the backbone of the research is discussed at the end of the chapter after all required information which influence the framework build up are given.

2.1. Resilience

Even though it is frequently used in the academic world, there is no consensus on the definition of resilience (Harrison & Williams, 2016; Kuang & Liao, 2020). A commonly used definition is from the UN International Strategy for Disaster Reduction: "Resilience means the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of the hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR, 2012, p.1). There are different kinds of hazards which require resilience. One is endogenous, meaning coming from within the system, such as revolutions, and the other is exogenous, which means coming from outside the systems, such as floods (Harrison & Williams, 2016). Resilience does not refer to an ideal state of the system. Resilience can also refer to an unwanted scenario, such as the resilience of poor neighbourhoods to change (Harrison & Williams, 2016).

2.2. Flood Resilience

In the specific case of flood resilience, some scholars represent the opinion that flood resistance in the form of dams and dikes is a big part of resilience. Others argue that resilience is the ability to adapt to or tolerate floods and recover from floods (Kuang & Liao, 2020). Industrialized countries have the tendency to heavily rely on resistance as part of their resilience with the mindset that flooding is hazardous and should be prevented in the first palace if possible. Rural communities in other parts of the world manage flood resilience without resistance, for example, in the form of houses on stilts (Kuang & Liao, 2020). A flood itself is not hazardous. Only if it poses a threat to human communities does it becomes a hazard (Kuang & Liao, 2020).

The academic literature on flood resilience portrays a spectrum of resilience interpretations. They can be summarised in three interdisciplinary frameworks: Resilience in Complex-Adaptive Systems, Engineering Resilience and system resilience. Engineering resilience has the aim to return to the status quo after a flood event by withstanding disturbance (McClymont et al., 2019). System resilience aims to "maintain[ing] system function in the event of a disturbance" (McClymont et al., 2019, p. 1153). The difference to engineering resilience is that it is not trying to 'bounce back' into the status quo but rather to 'bounce forward'. The Resilience in Complex-Adaptive Systems differs from the other two by using the disturbance for change, which creates long term resilience (McClymont et al., 2019).

2.3. Impacts of Floods

A flood often has serious consequences, even after the water is long gone. Over the last few decades, an increase in damages caused by floods has been reported. Three major factors cause this trend. First, a trend towards denser settlement along rivers with higher economic activity in flood-prone areas increases the economic impact of floods. Floods with the same intensity cause more damage if economic activities and settlements are in the path of destruction than in areas with a low population and low economic activity (Ionita & Nagavciuc, 2021). Since the areas, which are at high risk of floods, will stay popular for socioeconomic activities, the actual and potential damage caused by floods will further rise (Svetlana et al., 2015). The second reason is the trend of deforestation which takes away the protection of the nature service of the forests which absorbs precipitation. And finally, climate change is increasing extreme weather events such as extreme precipitation (Ionita & Nagavciuc, 2021). All of this cause the financial price of damage caused by floods to rise. In Europe there have been numerous floods that caused damages of over 1 billion Euros, as a result the damages caused through floods are a growing concern among the European nations (Svetlana et al., 2015). These economic costs summarise the destruction of socioeconomic necessities, such as agricultural land and infrastructure, including bridges, streets, water supply, as well as hospitals, schools and churches. Not only public infrastructure and buildings are often damaged, but also homes, which requires people to evacuate (Ionita & Nagavciuc, 2021).

In areas with profit from tourism, a respectful balance between the use of resources and tourism is essential. If an ecosystem is destabilized, it becomes more vulnerable to floods. However, especially in areas which rely on nature tourism, the richness of biodiversity is

essential. If floods damage the natural environment, the tourism that focuses on nature can decline since the primary attraction, in this case nature and biodiversity, is impaired. (Camarda & Grassini, 2003).

The damage caused by floods, which can be quantified by a financial calculation, also has a direct impact on the physical and mental health of the community. Studies covering high-or middle-income countries report an increase in anxiety, psychological distress, depression and post-traumatic stress disorder mong adults who have been impacted by floods. For children, an increase in bedwetting, aggression and stress symptoms were reported in studies (Stanke et al., 2012). Weilnhammer et al. compare the results of six studies and concludes that the "floods might not be directly associated with overall or cardiac mortalities but could possibly lead to the deterioration of mental health." (2021, p7). As mentioned before, floods can also have an impact of physical health, "such as the risk of death and injury, disease outbreaks, such as gastroenteritis, and water quality issues" (Walker-Springett et al., 2017, p66). When talking about the threat to physical health, it has to be differentiated between direct health impacts and indirect health impacts (Du et al., 2010). Direct health impacts results from exposure to flood water and the flooded environment. Such direct impacts can be drowning, injuries, electrical injuries and hypothermia. However, indirect or secondary health impacts are caused by the destruction of the natural and built environment. Such impacts include water or chemical contamination, which can lead to respiratory illnesses and communicable diseases (Du et al., 2010).

2.4. Community Flood Resilience Framework

Ever since resilience arrived as a concept in the development community, the need to measure resilience or the level of resilience arose with it. The need for resilience assessment tools served several purposes. On the one hand, measures aiming to increase resilience be assessed. On the other, resilience assessment frameworks can be used to assess the resilience of a community, district or country and identify points which require improvement (Campbell et al., 2019). The needs and requirements of an assessment tool can vary depending on what purpose they serve. That is why countless resilience assessment frameworks have been developed, especially since 2013. Even though there are plenty of flood resilience assessment frameworks, they differ in scope, focus and applicability. Many have a geographical focus, such as the Community Disaster Resilience Framework or Resilient Communities Scorecard, which focuses on the US (Bulti et al., 2019).

More relevant characteristics for this research are spatial scale, temporal scale and the level of applicability. Some frameworks like the Community Disaster Resilience Framework, Community Disaster Resilience Index and Australian Natural Disaster Index only focus on the higher end of the spatial scale, meaning they focus on the district or country level (Bulti et al., 2019). Furthermore, some flood resilience frameworks focus on both past and present states of resilience, whereas some include criteria for future assessments after floods. Another difference between frameworks are their aim. Most of them are designed to diagnose the level of resilience, whereas a few are also meant to not just diagnose but also be used as a tool for evaluation and planning.

For this research, the Community Flood Resilience Measurement Tool of Keating et al. (2017) was used since it fulfilled all the necessary requirements to assess the flood resilience of communities. In comparison to other frameworks, it only focuses on the community level and only integrates the influence of higher levels, such as the higher governmental influences, if applicable and necessary. The framework was designed by an alliance between non-governmental organisations, Zurich Insurance Group, and members of the academic field, and calls itself the Zurich Flood Resilience Alliance. The goal of the alliance was to design not just a theoretical framework but also an empirically validated measurement framework of resilience which can be applied by communities to measure their flood resilience. Another reason why this framework was chosen is its focus on past and present flood events, without necessarily having a second round of assessments after a flood event.

The framework combines and makes use of several pre-established concepts and integrates critical components of other frameworks in its assessment tool. The key concepts of the framework are flood risk management and resilience, for which they provide their own definition.

Keating et al. (2017) identified 88 sources of resilience. Each of the sources of resilience is assigned to one of the five capitals (5Cs): human, physical, financial, natural and social capital. The 88 sources of resilience are further connected to one of the resilience properties (4Rs): Robustness, Redundancy, Resourcefulness, and Rapidity. Additionally, the 88 sources of resilience are classified in two perspectives of the system level (community and enabling environment), ten themes and assigned to one of the five phases of the disaster risk management cycle. For a better understanding, an overview is included in Figure 1.

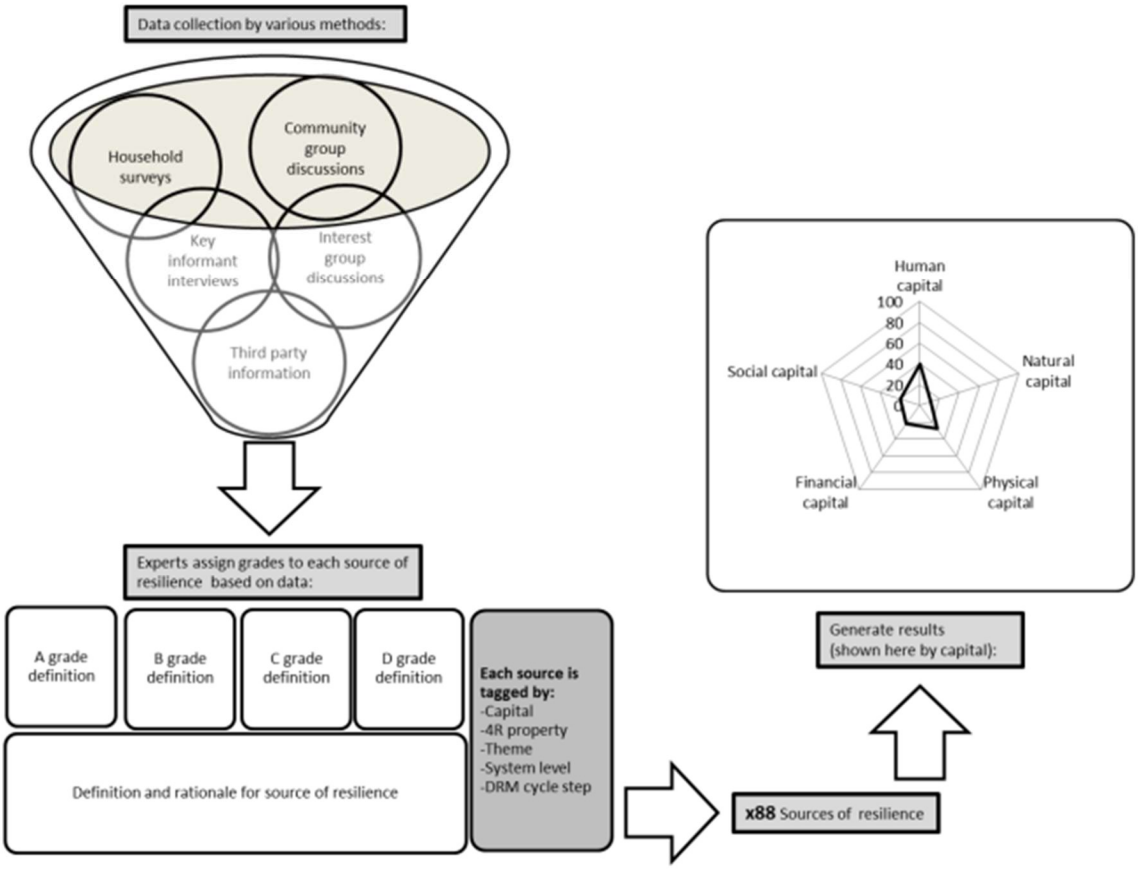

Figure 1. Zurich Flood Resilience Measurement Framework implementation process

Source: Keating et al. (2017, p.84)

As previously mentioned, the framework uses pre-established key components of other frameworks. The 5C are taken from the sustainable livelihood framework, which sees the 5C as the backbone of a community system. The idea is "that a livelihood is sustainable when it can cope with and recover from stresses and shocks" (Lax & Krug, 2013, p.6), which in this case is being applied to flood events. The theory implies that to achieve a sustainable livelihood, the 5C should be present (Department for International Development, 1999). Human capital includes the ability and capability to work and pursue a livelihood strategy. Social capital includes the strength gained through the organisation of a community, such as adherence to rules, mutuality of interest and leadership. Financial capital represents resources owned in the form of stock on the one hand, and external inflow of money such as labour income, pensions or other forms of financial liabilities on the other hand. Natural capital includes all the natural resources available, such as water bodies, forests and land. The physical capital contains mainly infrastructure and the opportunity costs it provides (Lax & Krug, 2013).

Keating et al. (2017) integrated four properties of a resilient system as they were defined by Bruneau et al. (2003). These properties are redundancy, resourcefulness, rapidity and Robustness (Bruneau et al., 2003). By assessing the 4Rs, the weaknesses and strengths of the system concerning one or more of these properties can be identified.

The disaster risk management (DRM) cycle was included in the framework by Keating et al. (2017) to identify if resources are evenly distributed throughout the cycle or if there is a special focus on either ex-ante or ex-post measures. The different stages of the DRM cycle are prospective risk reduction, corrective risk reduction, crisis preparedness, and coping. Since a disaster is an event unforeseeable and unpredictable event, each of the stages fluently transitions into each other and are highly interconnected. Thereby, two stages are for a short time, overlapping when transitioning into the next stage. By connecting the 88 sources of resilience to these different lenses, a holistic perspective on the resilience of the community can be created.

The framework of Keating et al. is very extensive and detailed in its incorporation of previous frameworks. To keep the framework applicable and feasible for this research, the idea of the 5Cs and their attached sources of resilience were taken over, while the DRM cycle, the 4Rs, and the themes and context are, even though of value, outside of the scope and relevance for this research. The reason for this is the focus, time and resource limitations and very specific scope of this research, which is, to some degree, already outlined by the formulation of the research question. It is acknowledged that the alignment of these properties was relevant for the construction of the original framework of Keating et al. (2017). Nevertheless, they do not contribute to answering the research question.

As shown in Table 1, the original assessment tool of Keating at al. (2017) propose the use of five data collection methods. One of them being household surveys. Due to the limited scope of this thesis, which does not allow for research on a household level, the 5Cs were reduced to 4Cs since the human capital explores the source of resilience provided from a household level. These four capitals are listed in the left column of Table 1.

Table 1. The four capitals and corresponding indicators of community flood resilience

	Indicators of resilience
Physical capital	Flood coping infrastructure
	Basic needs infrastructure
	Emergency infrastructure
Financial capital	Financial budget management
	Flood-related financial management decisions
	Financial safety nets
	Financial marked access
Social capital	Flood resilience governance
	Institutional capital
	Flood risk perception
	Community engagement in flood resilience planning
	Contingency planning
	Personal security and security of assets
Natural capital	Basin health
	Sustainable use of natural resources
	Conservation management plan
	Habitat connectivity
	Natural habitats maintained for their flood resilience services
	National legislation recognizes habitat restoration

Sources: Adapted from Keating et al. (2017) and Laurien et al. (2020)

By using the varimax rotation principal component analysis (PCA), Laurien et al. (2020) discovered that the 88 sources of resilience can be clustered in subcomponents, with the exception of natural capital due to its small number of indicators. This reduces the 88 sources of resilience into 23 indicators, of which four were from human capital and are not included in this research. This list of indicators can be found in the right column of Table 1.

The indicators of Table 1 are an integral part of this research. How they are integrated into the data collection and analysis and to the assessment of resilience are explained in the next chapter.

3. Methodology

In this chapter, the setup of the methodological aspects of this research will be explained. First, insights will be given in the research strategy which deals with the clarification of the research unit, the reasons for selection parameters as well as the boundaries and limitations of the research. Then, the data collection and analysis steps are explained in respective sections. To provide the required transparency, the last sections are dedicated to discussing the validity of the data and ethical considerations.

3.1. Research Strategy

3.1.1. Research unit

To assure that the outcome of this research is of high quality and relevance, the definition of a clear scope is needed. The focus of this research is on the Salzach River which has its origins in the area of Oberpinzgau and merges after 226 km into the Inn River. Along its way it gets feed by multiple mountain streams. Since an assessment of all communities along the shores of the Salzach River would have been too extensive, the geographical limits for this research are the borders of the district Zell am See. Within the district Zell am See, two municipalities were used to collect the data from, representatively for the whole district.

3.1.2. Selection of research unit

The focus of this research is on the communities within the border of Zell am See. Zell am See in not just a municipality itself but also an administrative unit with includes 12 municipalities. Two of these municipalities were selected to be representative of the communities along the Salzach River within the district. These who municipalities were chosen based on their history with flood events and the impact that floods have on their community. An additional factor was the size difference between the two municipalities. Mittersill has 6,267 inhabitants in an area of 132 km^2, whereas Uttendorf has 3,037 inhabitants on a larger area of 168 km^2. This difference allows for a better representation of different sized municipalities within the district of Zell am See. Lastly, they are not all located next to each other along the river but have at least one other municipality between them, which results in slightly different geographical conditions which are nevertheless still comparable.

3.1.3. Research boundaries and limitations

Flood resilience happens on multiple levels such as national level, community level as well as on a small scale on household level. Due to a limitation of resources and time, this research only focuses on flood resilience on a community level, which naturally excludes an assessment of the flood resilience on a household and national level. Furthermore, it is not claimed for the research to have a gapless assessment of the resilience of the communities since only one level, the community level, was taken into consideration within a limited time scope.

The assessment tool of Keating et al. (2017) which was introduced in Chapter 2 intended for ex-ante as well as ex-post assessment. Since floods are unpredictable and this research had a limited time available to conduct data collection, the focus is on ex-ante flood resilience and does not include ex-post data collection for comparison.

In cases of extreme precipitation, the soil on steep mountain slopes can get instable and cause mudslides, which can cause an additional natural disaster. However, these are not included in this thesis. Even though they are both caused by extreme weather events, the ex-ante and ex-post measures and the resulting impact differs to those of flood events.

Since the data collection took place within a set time frame which was coincidently within the summer month with a high risk of floods, some interviews were unfortunately not implemented. However, this does not compromise the quality of this research since enough interviews with comprehensive information transfer took place to compensate this limitation.

3.2. Data Collection

The method of data collection was influenced by the nature of the main research question and the sub questions, which are of qualitative nature. The objective of the research is to gain better understanding of the dynamic between a natural process and the impact it has on the affected communities. This requires qualitative research methods with multiple sources of data. Depending on the sub questions different data collection methods were used.

Table 2. Overview of data collection method, organized by sub-question

Research question	Required data	Data collection methods	Sources of Data
RQ1	Qualitative data on current and expected impacts	Desk research	Scopus, government publications, newspapers, publications of organisations/ institutes
RQ2	Qualitative data on natural, physical, social and financial factors	Desk research and Interviews	Scopus, government publications, newspapers, publications of organisations/ institutes Interviews of key figures with expertise on natural, social, physical or financial factors
RQ3	Qualitative data on level of resilience	Desk research and interviews	Scopus, government publications, newspapers, publications of organisations/ institutes Interviews of key figures with expertise on the municipalities and their social and institutional structures

The first sub-question is of explanatory nature which requires an elaboration of the general scene of impact on communities. For this purpose, desk research was used to gather required data. This includes the examination of documents from credible sources such as reports of governmental authorities, noteworthy institutes or organisations, or local newspaper articles. Multiple keywords were used to filter for sources with high relevance. Since the focus in on two rather small communities, the main sources of relevant data were articles of regional and national newspapers as well as governmental publications.

For the second sub-question, a combination of interviews and desk research was used to gather data. In total eight interviews were conducted with representatives with different expertise and viewpoints. The interviewees were both from governmental bodies as well as non-governmental organisations. During the interviews an open-ended question structure was used to acquire as much data as possible. Both Mittersill and Uttendorf are represented in the Interviews as shown in the left column of Table 3.

Table 3. Overview of interviews conducted

	Governmental representatives	Non-governmental actors
Municipality Mittersill	1	1
Municipality Uttendorf	0	1
District wide	3	2
Total	**4**	**4**

Some of the interviewees were in similar positions with similar expertise which allowed for a confirmation of the data. In Mittersill, one governmental representative agreed on giving an interview as well as the commander of the fire brigade. In Uttendorf, one interview was conducted with the commander of the local fire brigade. On a district wide level, two representatives of the civil protection agency, a contact person from the nature conservation NGO and a representative of a local initiative and the representative of the federal water engineering administration agreed on sharing their knowledge and viewpoints. A complete list of the participating parties can be found in Table 4.

Table 4. Interview partners and their type of actor

Interviewees	**Type of actor**	**Code for referencing**
Fire department Mittersill	Non-governmental actor	FDM
Fire department Uttendorf	Non-governmental actor	FDU
Civil initiative	Non-governmental actor	CI
Federation of Nature Conservation	Non-governmental actor	FNC
Forest office	Governmental actor	FO
Representative of the municipality of Mittersill	Governmental actor	MM
Civil protection services	Governmental actor	CPS
Federal Water Engineering Administration	Governmental actor	FWEA

Before any interview was conducted, an interview guide was designed, which included all the steps which each interview will include, no matter the person being interviewed. This interview guide can be found in the Appendix A. These protocol steps included the introduction of the topic, their right to stop the interview at any point and the request for their consent to record the interview. Following this, the questions were developed with the help of the framework. The indicators of resilience were used to formulate the research question, which automatically assured that each of the indicators will be included and covered in the interview process. For a better overview are the interview questions and their relation to the 4Cs listed in Appendix D. An overview what indicator was covered in which interview can be found in Appendix C. When comparing the interview questions and their relationship to one of the 4Cs (Appendix D), and the sources of information regarding the indicators of resilience (Appendix C), a slight difference can be noticed. This is the case because additional topics came up during the interviews, which resulted into a more thorough coverage of the indicators of resilience. Each interview was designed to provide a logical order of the questions tailored to the person being interviewed. Some questions were posed to multiple people, depending on the expertise of the interviewee.

All but two interviews were recorded, in these cases their consent was either audio recorded at the beginning. In cases where the consent was either not clearly audible or forgotten, the interview partners gave written consent which can be found in Appendix B. Four out of the six recorded interviews were audio recorded and then transcribed. The data from the remaining two interviews was saved by detailed notetaking in one case, and a written response to the interview questions in the other case. The transcripts were shared with the interviewees, if requested.

3.3. Data Analysis

The data analysis differed per sub-question. Since each of them make use of different data sources this requires data analysis which makes the most out of the collected data.

For the first sub-question, data collected through desk research was used. All the relevant data was collected and saved. When reading the documents, the impacts mentioned in each document were noted. After all the documents were read and all impacts on the communities were identified a list of all impacts was created. When the list was completed, it was scanned for repetitively mentioned impacts which were then combined. Following this the list of impacts was scanned for clusters of impacts which could be summarised in one category. This

way four major categories were identified: impact on infrastructure, financial costs and psychological impact, and impact of climate change

Since the first sub-question was also asking for current impacts as well as expected impacts. The impacts which are expected in the short and long term are treated as a separate category alongside the three previously mentioned categories of current impact. The expected impacts were summarised in one category since they all evolve around climate change.

For the second and third sub-question, the data collected through interviews and desk research were analysed to generate results. For this purpose, the software NVivo was used. In the software 19 different codes were created which were the indicators of resilience of the framework. All data was uploaded on NVivo and each information which was relevant for one or more of the 19 codes were marked and linked to the codes. After the coding was completed, the software allows for an overview of all information connected to each code which allows for an easier overview of the results of each indicator of resilience.

3.4. Validation of Data

As mentioned previously, this research made use of multiple data sources and collection methods. The combination of interviews and desk research increased the validity of the data, as the information gathered can contradict or support each other. Since the data comes from multiple sources, such as different interviews and publications, the repetition of certain topics or aspects assure the relevance and validity of the given information. Therefore, the triangulation of data through different collection methods and different sources, assures a high validity of the accumulated data.

To assure a that the data used for the research is acceptable for academic standards only sources with a high credibility were used, such as academic articles found on Scopus, governmental publication or newspapers. When it comes to the data collected through interviews, the focus was on choosing interview partners which had a high potential to provide data which is reliable because of their experience and position as a representative of organisation with relevant reference to floods.

3.5. Ethical Considerations

To assure a high ethical standard throughout the research, the details of the interview procedure and handling of the data were reviewed by the ethics committee of the Behavioural, Management and Social Sciences Faculty at the University of Twente. For this purpose, a detailed ethics assessment form was filled out, covering every aspect of the data collection and management. This also included possible safety measures to ensure that the interviews would not result in negative consequences for the interviewees.

Since the research included interviews with people, who are knowledgeable but also impacted by the floods, the interviewees were given the opportunity to stop the interview at any point without having to give an explanation. The interviewees were not forced or pressured to give an interview and consent was always given. All participants had the opportunity to withdraw their interview, if requested after the interview.

When looking for the source of resilience and areas which have the potential for improvement, it is not the aim to criticise individuals, organisations, or ministries for a lack of resilience. The research only assesses the level of resilience based on available data.

4. Results

In this chapter, the results of the research are presented based on the analysis of the collected data. Each section presents the results regarding one sub-question. Since the answers to the questions include several findings, each finding is elaborated on in a sub-section.

4.1. Current and Expected Impacts of Floods

The floods coming from the Salzach River impact the communities in several different ways. The most outstanding of them are the impact floods have on their infrastructure, the financial aspect of flood events as well as the psychological impacts. Additionally, are the communities already identifying impacts which are to be expected because of environmental changes.

4.1.1. Impact on infrastructure

The biggest impact that floods have on the communities is on infrastructure. During the flood, infrastructure such as roads, bridges and train tracks are flooded or unsafe for passage (Stadtgemeinde Mittersill, 2021; Salzburg24, 2021). Considering that the communities lie within a valley, the possibilities for bypasses are limited. The bridge in Mittersill which is part of the main road connecting all municipalities in the district of Zell am See is being lifted during floods (Stadtgemeinde Mittersill, 2021; Lovric, 2021). Bypasses are created but are not durable to channel as much traffic as the main road does (Salzburg24, 2021). This creates traffic jams and overuse of roads which are not designed to channel such extensive use (Berger, 2021; ORF.at, 2021).

Right after floods some streets require cleaning and minor restorations (Stadtgemeinde Mittersill, 2021). The bridge is essential to the infrastructure. It is a bottleneck which connects the municipalities upstream and downstream. However, it cannot be lowered immediately since the water has to return to its normal hight in order to be lowered again, this can require additional days.

In the long term. the biggest destruction to the infrastructure is on the train tracks. They are built on a dam along the shore of the Salzach Rover. During floods the tracks are getting undermined, washed away and heavily damaged (Die Presse, 2021). Repairs to reinstall the train tracks takes month with is limiting the public transport in the region significantly since it is the only train connection in the valley (Grießer, 2021a).

4.1.2 Financial impact

The destruction and limitations on the infrastructure also has financial consequences to the communities. Zell am See is a touristic region, which relies on their tourism sector as a source of income especially in the summer and winter months. With limited or destructed infrastructure, the tourism sector is restricted in its ability to function (Puchner, 2020).

Additionally, floods create, depending on their magnitude, considerable destruction which require costly investments to repair (Süddeutsche Zeitung, 2021). In the case of the destroyed train tracks, the damage caused it about 10 million Euros alone (Grießer, 2021a). These costs will be covers by the company who owns the train tracks and not by the communities. There are no records of the damage on in each municipality. However, the district of Salzburg reported a total damage of 30 million Euros in July 2021 (Hettegger, 2021), including 12 million Euros in damage on residential buildings and 11 on companies. Private households received a compensation from a disaster fund (Der Standard, 2021) of minimum 50% up to 80% (Hettegger, 2021).

4.1.3 Psychological impact

Even though the flood in 2021 was not as catastrophic as the flood in 2005, the impact on the mental state of local communities remains. After the flood infrastructure was built in 2015 to withstand a HQ 100 flood, the community members felt a sense of safety (Pallinger, 2022, Grießer, 2021b). After the flood in the summer of 2021 was identifies with a severity of a HQ300 flood, the sense of safety became first cracks. The flood infrastructure was tested to its limits and during the peak of the 2021 flood it was feared that the dam of the retention base would become instable (Berger, 2021; Lovric, 2021). This uncertainty brought back worries about inadequate flood infrastructure and the consequences if flood infrastructure failure (Pallinger, 2022; Überparteiliche Bürgerinitiative zum Schutz des Lebensraums Oberpinzgau, n.d.). Ultimately, the sense of safety against floods decreased and a state of alarm with high precipitation returned (Grießer, 2021b; ORF.at, 2022).

Additionally, during a flood like in 2021 the stress level of not just the emergency services but also the community member who participated in flood protection measures are high in comparison to normal days (Berger, 2021). The emergency services are on continuous operation to minimize the damage and react to the damage caused by the flood (Baldauf, 2022). Especially the fire departments are under the pressure of caring the responsibility of coordinating all measures (Salzburg24, 2021). The fire departments in the communities along

the Salzach are all on a voluntary base. Therefore, floods which are of a bigger magnitude can require the attention of the fire department and voluntary helpers for days (Berger, 2021) in addition to their responsibilities they have as private people (Baldauf, 2022; Salzburg24, 2021).

4.1.4 Expected future impacts

When looking at what the communities might expect in the future in terms of the impact of floods, climate change plays a central role. The communities expect an increase in the frequency and intensity of floods. Because of an increase in temperature, the snow line is increasing in altitude. This results in more surface water runoff which eventually ends up in the Salzach (Kaindl, 2022). Furthermore, a higher transportation of sediments is expected since areas of permafrost on high altitudes are thawing, which exposes sediment to the precipitation (Kaindl, 2022). This impacts the communities negatively, as it can require more frequent maintenance work to assure a high capacity to channel the runoff of the Salzach river (Grießer, 2022, ORF.at, 2022). In 2021, the flood infrastructure, which was built to resist a HQ100 event, managed to prevent a major catastrophe even when faced with a HQ300 flood. Nevertheless, the flood infrastructure was tested to its limits. Climate change is expected increasing the likelihood of such floods which will keep testing the flood infrastructure of the communities.

4.2 Factors that Influence Community Resilience

The analysis of interviews and the desk research show that multiple factors influence flood resilience, both positively and negatively. In chapter 2, the four capitals of resilience were introduced. This section is organised according to the findings for each of these capitals.

4.2.1 Physical capital

Regarding the physical capital, the flood prevention infrastructure is the strongest influencing factor. Within the region, the flood coping infrastructure is designed to withhold a flood with the likelihood of 100 years (Interviewee MM). All communities in the research area have a active flood protection which is being continuously improved after ever flood event with the help of hydraulic calculations (Interviewee, FWEA). In the year 2021, this capacity was put to the test with a 300-year flood (Kaindl, 2022) (Interviewees, CI, MM, FDM, FDU). The flood protection infrastructure successfully protected the community of Mittersill (Interviewees

FDM, MM). Nevertheless, the flood protection infrastructure was at the limit of its capacity (Interviewees FDM, CI, MM). Since floods are expected to occur more frequent with a high intensity, more flood retention areas are in the planning (Interviewees FO, MM, CI, FDM, FDU). However, since flood infrastructure in the valley does not provide much more room for improvement (Interviewee FWEA), the additional retention areas are planned in the side valleys, to prevent the water from accumulating in the populated valley (Interviewees FO, MM, CI, FDM, FDU).

In general, the infrastructure is exposed to floods. The B168, which is the main road connecting the municipalities along the Salzach, is built on a dam and therefore protected from HQ 100 floods (Bundeswasserbauverwaltung, 2012 and Interviewee FWEA). However, during the HQ300 of 2021 the water levels within the retention are reached a level which also required the flooding of the B168 (Interviewees CI, MM, FDM). Furthermore, the only train rails are placed in direct proximity to the Salzach, which causes it to be damaged after every major flood event (Interviewees CI, FWEA). This exposes the crucial infrastructure to the floods, which decreases the resilience of the communities. During the past floods, there were no accounts of contamination of drinking water or other threats to basic needs such as access to food and shelter (Interviewee CP).

The emergency infrastructure is designed to function within the natural boundaries of a mountain setting. Communication between the operational command, the municipality and the civil population takes place via multiple channels. For one can a dedicated alarm app warn of hazards such as floods or other dangers. Other means of communications are online information, sirens and social media messages (Interviewees FDM, FDU, MM). The water level within the Salzach River is publicly accessible via the websites of the municipalities as well as via apps (Interviewees, FDM, MM). Also, the media, such as radio and (online) newspapers, is being used to inform and warn the population. In an emergency with a water level over five meters, the sirens will go off (Interviewee FDM). During a flood event multiple organisations involved such as the police, the volunteer fire fighter, the water rescue service as well as Mountain rescue service and red cross if needed (Interviewees FDM, FDU). In a state of emergency, the operational command also has access to support from the military (Landesverteidigung, n.d.). Challenging is the geographical setting, which makes it harder to reach people in an emergency. The main infrastructure being the B165, which is a federal road connecting all communities in the area, is not accessible during an HQ300 flood (Interviewees CI, MM, FDM) . Additionally, is the air space also not an access possibility

during an event with high precipitation (Interviewee CP). This would pose a challenge to the emergency infrastructure during a flood event.

4.2.2 Financial capital

In the State of Salzburg, the financial responsibilities are well defined with regard to flood-related investments. Both the municipalities but also the national government has clear responsibilities when it comes to flood-related investments and therefore is having a budget which can cover flood related costs (Interviewees FWEA, MM, CPS). When it comes to needed infrastructure, a five-year plan is being developed by the responsible Federal Water ministry (Interviewee FWEA). Depending on required projects, a budget is being calculated. In the municipalities, there is budget for the running expenses to keep the flood infrastructure in good condition, and a second budget for new flood related costs, such as infrastructure or material needed by the emergency services (Interviewee MM).

When it comes to flood related financial investments along the Salzach, the Federal Hydraulic Engineering Funding Act prescribes that the national government is responsible to cover the expenses (Interviewee MM), however a certain percentage always needs to be covered by the beneficiary community. On average the 85% of the cost are covered by the national government and 15% by the communities (Interviewees MM, FWEA). In the case of the flood protection of Mittersill, which costs 13 million Euros, 82% of it was covered by the government, 3% by the municipality and 15 % by the Water Association Salzach-Oberpinzgau, an association of communities (Interviewee MM). These investments are needed to prevent reoccurring damages and therefore costs, whenever the water level of the Salzach rises.

During the flood of 2021, the industrial zone was completely flooded (Interviewees FDM, FDU, MM), which caused major economic loss and a long recovery time until the companies could continue their work (Interviewee FDM). Additionally, the region is highly dependent on tourism, especially during the summer month. The temporary blockage and long-term damage to infrastructure such as the train rails can limit tourism (Interviewees MM, CI).

In the case of damages caused by floods, the disaster assistance act demands the federal state in cooperation with the different states to provide financial damage coverage. This applied to damages both on the community level, and on a private level such as damages on the house (Interviewees MM, CPS). However, the degree of compensation differs. At the municipality level, the disaster fund covers 50%, whereas for citizens it covers between 30% to 80% of the

damages (Land Salzburg - Katastrophenfonds, n.d.) (Interviewees MM, CPS). The fund furthermore covers the expenses of materials and measures which are required for the immediate protection of communities (Interviewee FDM).

4.2.3 Natural capital

Over the past decades and centuries, the Salzach River was continuously impacted and altered by human actions. Reasons for such actions include making better use of the land around it and protecting the communities along it from floods. This changes the sediment transport, the runoff and land characteristics along it, which automatically also changes the characteristics of floods (Interviewees FWEA, FNC).

During times of normal water levels, the Salzach is accessible through a bike road. Along the bike road are benches in close proximity to the river. However, is the Salzach itself not used for recreational purposes (Interviewees MM, CI). The connection between the communities and the River is not significantly contributing to the resilience of the communities.

There is no long-term conservation management plan for the Salzach River (Interviewee FNC). However, the basin health is assessed occasionally. In 2012, the action group Lebensraum Salzach (in English Habitat Salzach) initiated an assessment of basin health not just regarding single projects but for the whole length of the river (Interviewee FNC).

Since flood protection measures fall under the disaster prevention, there is no need for an approval for measurements for an ecologist (FWEA). When an area for new flood related measures is under nature protection, the Nature Conservation Agency has to give approval. The parameters for a protected area are written down in the Nature Conservation Act (Salzburger Naturschutzgesetz 1999- NSchG StF: LGBI Nr 73/1999) which specifies which areas stand under protection (Interviewee FNC). If a measure does not contribute to disaster prevention, a permit is needed which assures that measures are in harmony with the water management law. In that case, an aquatic ecologist conducts the assessment (Interviewee MM).

The area around the communities is dominated by forests. These forests serve indirectly towards flood protection. Since the communities are situated in a valley, the precipitation in the mountain runs towards the deepest point, which is the valley. The forests have the capacity to hold 70% of the precipitation and can delay the water flowing towards the valley. Because of these and additional nature services, the forest is called as “Schutzwald” which translated means protection forest (Bundesministerium für Land- und Forstwirtschaft,

Regionen und Wasserwirtschaft, n.d.). It is required by law that in case of deforestation the forest will be replaced within 3 years. If a piece of land is needed for development, the forest will be increased somewhere else as compensation (Interviewee FO). Apart from the forest, there is little evidence of nature-based food protection services.

4.2.4 Social capital

Social capital and capacity are the most significant factor that affects the resilience of communities. Both during and after floods, community engagement was very high. The citizens of the communities actively contributed to the flood protection actions as well as helping other citizens who are more impacted by the flood (Interviewees FD1, FD2, CI). This community strength is a crucial factor for resilience since the fire brigade alone would not have the capacity to fulfil all required measurements. Community engagement is the core ingredient to the resilience of the communities since their combined effort allows them to combat the flood and mitigate the damage. This is managed through cooperation under the directions of the fire brigade (Interviewees FD1, FD2), and through neighbourhood support, which is the spontaneous initiative of locals, and not an organisation.

Based on thorough documentation of the emergency services during a flood event, weaknesses in the infrastructure are detected and corrected after floods (Interviewee FD1). Thereby, improvements were made through continuous evaluation of the flood protection infrastructure (Stadtgemeinde Mittersill, 2022 and Interviewees MC, FWA). Additionally, the Bundeswasserbauverwaltung in cooperation with the municipalities have made plans to assure continuous flood protection through additional retention basins in the Tauern Valleys (Interviewees FWA, MC, CI, FD1, FD2). These continuous improvements allow for a high level of resilience since the protection measures are continuously adapted to changing climate patterns caused by climate change.

After the build of the flood protection measures in 2005 and 2006, the communities along the Salzach assumed that the flood protection was sufficient since it was built for a flood with the statistical likelihood of 100 years (Interviewees CI, FWA, MC). This caused a feeling of secureness, which did not reflect the reality. After the floods in 2014 and 2021, flood risk awareness of the communities increased (Interviewee CI). This is also demonstrated by the local sensibility towards the effects of heavy precipitation. Because of this awareness, a local initiative was formed that demanded better flood protection. Such level of flood risk

awareness is crucial to resilience since it results in adequate behaviour during the event of a flood, which minimises the risk of damage and casualties.

Finally, the institutional capital significantly contributes to the level of resilience of the communities. The responsibilities regarding every aspect of floods are predefined and cover all aspects. This allows for a clear allocation of responsibilities and good coordination during and after the flood. This organisation reaches from the local level up to the national level. The responsibilities regarding financing as well as actions taken are clear and allow for efficient and fast actions during a flood.

4.3. Level of Community Resilience

4.3.1 Physical capital

When looking at the factors which influence the physical capital, the physical capital contributes to the resilience of the communities along the Salzach River. The emergency infrastructure is with its means for communication, and emergency services and facilities are sufficient (Interviewees FDM, FDU, CPS). In a case of emergency, multiple governmental actors, as well as voluntary organisations, have predefined responsibilities (Interviewees FDM, FDU, CPS) which contribute to the ability of the community to cope with floods which reflect well on their resilience.

The flood coping infrastructure is executed to withstand an HQ100 flood and, with repeated improvements, was able to withstand a HQ300 flood (Kaindl, 2022 and Interviewees MM, FWEA). This way, the community was not protected from the water masses, which highly contributed to resilience through disaster prevention.

The basic need infrastructure, however, is heavily impacted by floods. The main road connecting the municipalities along the Salzach is protected by its position on top of a dam (Interviewee FWEA). Nevertheless, at a certain water level, this street is flooded as well (Interviewees FDM, CI). Concerning public transport, is the flood sill having severe impacts on the train rails (Huber, 2021), because of its close proximity to the river (Interviewees CI, MM). In total is, the physical capacity at a good standard, with no immediate need for improvement. This has to be considered within its geographical limitations, which do not allow for unlimited room for physical structures.

4.3.2 Financial Capital

The financial factors impacting the community's resilience toward flood events are highly contributing to their ability to cope with floods. The clearly assigned responsibilities regarding the financial budget management (Interviewees FWEA, MM, FO) assure the capability not only to make flood-related investments, but also to ensure the maintenance of structures and services to ensure a high standard. Furthermore, are flood-related financial decisions are only implemented if the involved parties have the capability to finance the projects (Interviewees MM, FWEA). This is assured through five-year plans, which prioritise important projects (Interviewee FWEA), as well as clear communication between municipalities and government about how much financial burden can be put on the communities (Interviewee MM). The disaster fund is a financial safety net from the government to minimise the financial burden of individuals (Land Salzburg - Katastrophenfonds, n.d.) but also the municipality after a disaster (Interviewees MM, CPS). Flood events, however, still have an impact on local businesses such as tourism. The case of the 2021 flood also damaged the local industry (Interviewees FDU, FDM, MM). Since the dam surrounding them has since been increased (Interviewee FDM), this is not getting considered negatively anymore towards the level of resilience. Therefore, the financial capital is immensely contributing towards resilience since it allows for investments to prevent damage caused by floods, as well as allows for recovery after a flood event which is the best possible practice for managing the risk.

4.3.3 Natural Capital

The natural capital is not contributing to the community's resilience as strongly as financial and physical capital. Within the indicators of resilience, the maintenance of the forest for nature-based flood-related services (Interviewee FO) is the strongest contributor to the community's flood resilience. The low habitat connectivity (Interviewees MM, CI) and lack of conservation plan (Interviewee FNC), however, are not contributing to flooding resilience. The land use for settlements and agriculture hinders renaturation projects, which could have positive impacts on the resilience of nature-based services (Interviewee FNC). The river basin's health is neither negatively nor positively contributing to the resilience since the data concerning this is not sufficient enough to draw a conclusion. In summary, it can be said that the data shine a light on some deficits and room for visible improvements, such as the need for better use of nature's capacity to contribute to flood mitigation and prevention.

4.3.4 Social capital

The social capital is a big contributor to the high level of flood resilience. Members of the community voluntarily contribute to the flood resilience either in the form of volunteer firefighters or under the coordination of the firefighter in a flood event (Interviewees FDM, FDU). The community shows their resilience during a flood by coming together as a community to withstand the flood and its impacts.

Furthermore, the predefined responsibilities in case of an emergency between the emergency services, the municipality and the district (Interviewees FDM, FDU, MM, CPD) contributes to a high level of resilience through clear coordination in a case of emergency.

The awareness of the community members of the risk of high precipitation assures their own safety. By making adequate preparations (Interviewee CI) and monitoring the water levels (Interviewee FDU), community members can decrease the potential damage through their own actions, which contributes to the resilience of the whole community.

5. Conclusion and Discussion

This thesis had three sub-questions that were formulated towards answering a main research question. The first sub-question was: "*What are the current and expected impacts of floods on the communities along the Salzach River?*". The current, most relevant impacts of floods on the community is the destruction of infrastructure and buildings. As a result, considerable investments are needed to rebuild and repair the damages. However, though not as visible as the destruction, the floods also negatively impact both emergency services and community members. Floods cause high stress levels among emergency services because of their high responsibility and often long duration of missions. After the flood in 2021, the sense of safety among community members, given by the flood infrastructure, is not as strong as before, since the infrastructure reached its capacity limit.

The second sub-question was: *"Which natural, physical, social and financial factors influence the flood resilience of the communities along the Salzach River?"* Over time, the resilience to floods has improved, which results from the continuous improvement and adaptations to the changing environment. The financial capital of the community allows them to adapt their flood infrastructure and to financially compensate for the damages caused by floods contribute to the resilience. Additionally, the physical capital contributes to resilience since all communities have an active flood protection system which is continuously improved after every flood event. The social capital is also strongly contributing to their resilience since the community is engaged highly engaged in flood-related measures. Even though voluntary organisations such as the Firefighters or local initiatives are formed, the public is also involved and aware of flood risks in case of emergency. Even though the nature-based services of the forest are acknowledged and employed, other nature-based solutions are not made use of. The absence of conservation plans or regular assessment of the basin health are neither positively nor negatively influencing the resilience of the community.

The thirds sub-question revolved around: *"How resilient are communities along the Salzach River to flooding?"* The community along the Salzach developed a high level of resilience up to this point through repeated experience with flood events. Even though their natural capital leaves room for improvement, their physical, social, and financial capital is well established and highly contributes to the resilience of the community.

The main research question "*How should the flood resilience of communities along the Salzach River be improved?"* can be answered through the combined findings regarding the

three sub-questions. The physical component of the communities requires continuous adaptation to the changes in weather patterns caused by climate change. Even though the social component of community resilience is established, most of the community engagement is motivated by a bottom-up involvement, such as civil initiatives and voluntary help during a crisis. However, there is no strong top-down involvement of the community members in the resilience building of the community. Such involvement, is limited to the sharing of relevant information through media, and online announcements. The financial capital is already strongly developed and does not require current improvement. Even though the region has limited capacity due to settlements and agricultural use, the incorporation of nature-based flood prevention solutions could be further developed to strengthen the flood resilience.

There are no notable differences in resilience between the two municipalities of Mittersill and Uttendorf. This could be due to the fact that the only comparable source of information were interviews with the who fire departments, which did not report any notable difference. The other interviews were often representative of the entire region such as the forest office, the civile services and the civil initiative. The desk research also did not reveal any noticeable differences.

When comparing the results of this research, some similarities with previous research can be found. Similar to other research of Ionita & Nagavciuc (2021) and Svetlana et al. (2015), the impact of floods on the infrastructure and destruction of other built environments could be identified. Additionally, the economic impact caused by the destructive nature of floods was identified in this research as well as in the previous research of Svetlana et al. (2015). In comparison to previous studies, this research did not identify impacts on the physical health as a result of floods. However, both this and previous studies of Stanke et al. (2012) and Weilnhammer et al. (2021) identify a psychological impact.

When comparing the findings of this research to the findings of Campbell et al. (2019), both similarities and differences can be named. Both this research and Campbell et al. (2019) identify physical capital to have a positive impact and the natural capital to have the least impact on the communities' resilience. In contrast, the analysis of the communities along the Salzach River shows that the financial and social capital considerably contributes to their resilience, whereas Campbell et al. (2019) find the social capital and financial capital to be generally a weak contributor to resilience. When looking at the differences, it must be mentioned that Campbell et al. (2019) also included less economically strong countries than

Austria in its research. The financial capacity to make flood related investments, could be partly attributed to the economic wealth of Austria. About the social contribution to the resilience, no obvious reason can be given to explain the differences.

The research was conducted within a limited time scope, because of which resilience on a national and household level could not be included. The time constraint furthermore limited the number of interviews that were conducted. Therefore, this research is based on the insight of the most relevant representatives. Since flood events are unforeseeable and not within the timeframe of this research, only an ex-ante analysis of flood resilience could be conducted.

A reoccurring topic throw-out this research was the effects of climate change on the community. Therefore, it would be of high relevance for future research to be conducted on the topic of the effect of climate change on alpine floods. Considering that the alpine region consists of different climate regions, especially the region surrounding the Hohe Tauern with its glaciers, it would be of relevance for the communities along the Salzach River. As previously mentioned, the inclusion of the household level was not possible in this research. However, this component could contribute considerably to generating an even more detailed picture of community resilience and would therefore offer a relevant entry point for future research.

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Appendices

Appendix A. Interview Guide

Date: Start: End:

Person:

In person: Online:

Introduction:

- Introducing myself
- Introducing the topic of research
- Asking for consent to record the interview
- Informing the interviewee that the interview can be stopped at any time
- Informing that the interviewee does not have to answer the question if they do not feel comfortable or confident enough in their knowledge
- Asking if the person being interviewed has any questions before the start of the recording.

Start of recording

Introduction

Could you please introduce yourself and your position within your organisation?

Questions following the 4C

(List of questions in Appendix D)

Finishing question

Would you like to add anything else about the topic of flooding along the Salzach River?

Ending:

- Offering to share the research results
- Offering to share the transcript of the interview

Appendix B. Informed Consent Form

Name:

Datum des Interviews:

Interviewende Person: Katharina Götz

Ich erkläre mich dazu bereit, im Rahmen des genannten Forschungsprojekts an einem Interview teilzunehmen. Ich wurde über das Ziel und den Verlauf des Forschungsprojekts informiert.

Ich bin damit einverstanden, dass das Interview mit einem Aufnahmegerät aufgezeichnet wird. Die Audiodateien werden nach Vollendung und Benotung der Masterarbeit gelöscht. Die Audiodateien werden ausschließlich dazu verwendet, um Transkripte zu verfassen. Das Transkript wird, wenn gewünscht, zur Überprüfung mit dem Interviewpartner geteilt. Auch wird nach Vollendung der Masterarbeit, diese den Interviewpartnern übermittelt.

Ich bin damit einverstanden, dass einzelne Sätze aus den Transkripten, die nicht mit meiner Person in Verbindung gebracht werden können, als Material für wissenschaftliche Zwecke, im Ramen der Masterarbeit, genutzt werden können.

Meine Teilnahme an der Erhebung und meine Zustimmung zur Verwendung der Daten, wie oben beschrieben, sind freiwillig. Ich habe jederzeit die Möglichkeit, meine Zustimmung zu widerrufen. Durch Verweigerung oder Widerruf entstehen mir keine Nachteile. Ich habe das Recht auf Auskunft, Berichtigung, Sperrung und Löschung, Einschränkung der Verarbeitung, Widerspruch gegen die weitere Verarbeitung meiner personenbezogenen Daten. Unter diesen Bedingungen erkläre ich mich bereit, das Interview zu geben, und bin damit einverstanden, dass es aufgezeichnet, verschriftlicht und ausgewertet wird.

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Ort, Datum Signatur

Appendix C. Sources of Information regarding Indicators of Resilience

Indicators	Fire Department (FDM/FDU)	Federal Water administration (FWEA)	Forest administration (FO)	Civil initiative (CI)	Nature conservation organisation (FNC)	Civil protection (CPS)	Municipality (MM)
Flood coping infrastructure							
Basic needs infrastructure							
Emergency infrastructure							
Financial budget management							
Flood-related financial management decisions							
Financial safety nets							
Financial marked access							
Flood resilience governance							
Institutional capital							
Flood risk perception							
Community engagement in flood resilience planning							
Contingency planning							
Personal security and security of assets							
Basin health							
Sustainable use of natural resources							
Conservation management plan							
Habitat connectivity							
Natural habitats maintained for their flood resilience services							
National legislation recognizes habitat restoration							
*Physical capital							
*Financial capital							
*Social capital							
*Natural capital							

Appendix D: Interview question and their relation to the 4C

Physical capital
*Financial capital
*Social capital
*Natural capital

Forstamt:

1. Wie trägt der Wald zum Hochwasserschutz bei? – Stichwort schutzwald
2. Gibt es spezielle Maßnahmen um die Salzach herum?
3. Gibt es bestimmte Projecte oder Maßnahmen speziell für den Hochwasserschutz?
4. Sind die Leistungen oder der Beitrag den die Wälder leisten in den Hochwassermanagement Plänen enthalten?
5. Gibt es eine Koordination zwischen dem Hochwasserschutz und dem Forstbehörde?
6. Wie wird sicher gegangen das genügend Fläche bewaldet ist um zum Hochwasserschutz beitragen zu können?
7. Was können Gründe für den Verlust von Forstfläche/Wald sein?
8. Wer ist zuständig für die Finanzierung des Forstamt?
9. Gibt es eine spezielle Finanzierung dafür dass der Wald zum Hochwasserschutz beiträgt?

Naturschutz:

1. Wie wirken sich aktuelle Hochwasserschutzinfrastrukturen im Pinzgau auf das Ökosystem der Salzach aus?
2. Werden beim Bau neuer Hochwasserbewältigungsmaßnahmen die Gesundheit des Flusseinzugsgebiets berücksichtigt und die Auswirkungen vor der Umsetzung bewertet?
3. Wird die Salzach als natürliche Ressource nachhaltig genutzt?
4. Gibt es einen Naturschutzmanagement Plan speziell für die Salzach, um die Gesundheit des Ökosystem für die Zukunft zu gewährleisten?
5. Werden die Hochwasserschutzleistungen von Ökosystemen (z.B. Speicherung von Wasser) des Flusseinzugsgebiets bewusst genutzt und als Teil der Hochwasser Strategie anerkannt? Wenn ja, welche? Wenn nicht, weshalb?
6. Erkennt die nationale Gesetzgebung die Wiederherstellung und Erhaltung von Lebensräumen in Flüssen und an Flussufern an? Wenn ja, wo ist dies festgeschrieben?
7. Welche Änderungen würden sie gerne beim Hochwasserschutz im Pinzgau sehen?
8. Gibt es wichtige Informationen zum Hochwasserschutz, die ich mit meinen Fragen nicht abgedeckt habe?

Feuerwehr:

1. Ab wann wird vor Hochwasser gewarnt/ was muss passieren?
2. Wie funktioniert die Kommunikation einer Hochwasserwarnung? Wie werden sie benachrichtigt?
3. Wie wird die zivile Bevölkerung benachrichtigt?
4. Können sie bitte erklären welche art von Arbeit sie leisten bevor ein Hochwasser eintritt?

5. Was für Arbeit leisten sie wärend eines Hochwasserereigniss?
6. Was leisten sie nach einem Hochwasser?
7. Außer der Feuerwehr, welche Organisationen/ Einsatzkräfte sind bei einem Hochwasser im Einsatz?
8. Wer koordiniert die Einsatzkräfte?
9. Wer finanziert die Hochwasserbezogenen Einsätze? Wer finanziert das und die Ausrüstung?
10. Gibt es aktive Gemeinschaftshilfe vor, während und nach einer Flut? Wenn ja, in welcher Form?
11. Wie bereitet sich die Zivilbevölkerung auf eine Flut vor?
12. Gibt es Informationsveranstaltungen für die Zivilbevölkerung um den eigenschutz zu erhöhen?
13. Gibt es für die Feuerwehr Möglichkeiten zur Weiterbildung?

Bürger Initiative:

1. Wie beurteilen sie den aktuellen stand der Infrastruktur zur Hochwasserbewältigung?
2. Welche Maßnahmen sollten aus ihrer sicht in der Zukunft ergriffen werden, um die Infrastruktur zu verbessern
3. 2021 sind während dem Hochwasser die Zug Gleiße unterspült worden, gibt es sonst noch Infrastruktur die während einem Hochwasser gefährdet oder unbrauchbar sind?
4. Ist sich die Bevölkerung der Risiken die ein Hochwasser mit sich bringt bewusst?
5. Welche Maßnahmen ergreift die Bevölkerung um sich selbst zu schützen?
6. Abgesehen von der Pedition ihrer Bürger initiative, kann sich die Zivile Bevölkerung sich in die Hochwasserschutz planung einbringen?
7. Gibt es während einem Hochwasser abgesehen von der Freiwilligen Feuerwehr noch andere freiwillige initiativen wie z.B. Nachbarschaftshilfe?
8. Wie ist der Bezug zur salzach in Zeiten wo der Pegel auf einem normalen Niveau ist?

Gemeinde:

1. Wenn neue Hochwasserschutz Maßnahmen umgesetzt werden, wer musszustimmen?
2. Wie oft wird evaluiert ob der Hochwasserschutz ausreichend ist?
3. Welche Pläne gibt es um den Hochwasserschutz zu verbessern
4. Wie kann sich die Bevölkerung am Hochwasserschutz beteiligen?
5. Wer ist für die Finanzierung des Hochwasserschutzes zuständig?
    a. Wie groß ist das Budget?
6. Wer kommt für die Schäden an der Infrastruktur auf nach einem Hochwasser?
7. Werden private Menschen für die Schäden kompensiert? Oder müssen sie sich selbst versichern?
8. Leidet die lokale Wirtschaft under den Hochwassern?
9. Wozu wird die Salzach zu normalen Zeiten genutzt?

Katastrophenschutz:

1. Gab es durch Hochwasser schon einmal Probleme mit der Grundversorgung der lokalen Bevölkerung?
2. Wenn die Infrastruktur unbrauchbar ist, wie wird sicher gegangen dass Notfalldienste die Bevölkerung erreichen kann? Gesundheitsversorgung?

3. Gibt es Maßnahmen um die Bevölkerung auf einen Ernstfall vorzubereiten?
4. Haben sie das Gefühl die Bevölkerung schätzt die Risiken die ein Hochwasser bringt richtig ein?

Federal water administration:

1. Welche Schutzbauten gibt es entlang der Salzach im Pinzgau bereits?
2. Wie errechnet sich das budgt das für den Hochwasserschutz zur verfühung steht? Werden zuerst die kosten für die Masßnahmen errechnet und dann die finanzierung bereitgestellt? Oder müssen die Maßnahmen sich einem budget anpassen?
3. Wer kommt für die Kosten auf?
4. Schätzen Sie das Budget als hoch genug ein?
5. Wenn es darum geht Entscheidungen zu treffen, wer ist darin involviert und wessen zustimmung braucht mann?)
6. Wie oft wird die effictivität der Maßnahmen evaluiert?
7. Gibt es Ziele und Pläne zum Hochwassermanagement? Wenn ja, was ist ihr Zeitrahmen?
8. Aufgrund des Klimawandels wird es hochwasserereignisse öfter und intensiever geben, wie wird der Hochwasserschutz diesem Wandel angepasst?
9. Wie werden die Auswirkungen von Hochwasserschutzmaßnahmen auf das Ökosystem Salzach gemessen?