Exploiting damage claim records of public insurance companies for buildings to increase knowledge about the occurrence of overland flow in Switzerland

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ABSTRACT

Overland flow is difficult to assess because direct data is missing. As Swiss public insurance companies for buildings cover overland flow along with other hazards, we exploited their records to investigate the occurrence of overland flow indirectly. With a novel classification scheme, it is possible for the first time, to distinguish claims related to overland flow from inundations caused by watercourses. We analyzed gapless data records from 1991 to 2013 of the cantons Neuchâtel, Fribourg, Nidwalden and Graubünden, each representing a different typical Swiss landscape. Altogether, roughly 40-50 % of the damage claims can be associated with overland flow, which account for 20-30 % of total loss in that period. However, the inter-cantonal differences are large and reflect the embedment of overland flow in the landscape's geographic setting. Finally, looking at averages per km^2 and year, we found that pre-alpine Fribourg is affected most by overland flow. As an outlook, we are confident that the presented methodology can be used to start studying overland flow from a more process-oriented perspective.

KEYWORDS

overland flow; inundation and flooding; damage claims; public insurance companies for buildings

INTRODUCTION

Post-damage analyses in the field of flood hydrology highlight that not only overtopping rivers and lakes cause a substantial amount of loss. Reportedly, about fifty percent of all damages to buildings are caused by overland flow (Bezzola and Hegg, 2008). Overland flow propagates over the land surface as thin sheet flow or anastomosing braids of rivulets and trickles, until the flow reaches or is concentrated into recognizable channels (Chow et al., 1988; Ward and Robinson, 2000). Thus, overland flow is not constrained to a riverbed, but occurs diffusely in the landscape. Furthermore, overland flow is generally associated with a short response time and practically no advance warning, which makes it difficult to observe and study the process directly. Maybe that is the reason why, in spite of the existence of several practical tools to assess the hazard of overland flow (Kipfer et al., 2012; Rüttimann

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and Egli, 2010; Bernet, 2013), little is known about where and when overland flow occurred in the past and will occur in the future.

As there is no direct information about the occurrence of overland flow in space and time, traces of the flow's propagation can be found wherever the process has caused detectable damages, or claims thereof. These can be used as a proxy for the occurrence of overland flow. Data sources implicitly containing such information are house owners' damage claims recorded by Swiss Public Insurance Companies for Buildings (PICB).

Our overarching goal is to improve the process understanding of overland flow. In this paper, we want to demonstrate that damage claim records can provide very useful, indirect information about the occurrence of overland flow in space and time. Furthermore, by looking at the total number of claims as well as total loss related to overland flow and inundation from watercourses respectively, we want to highlight the relative relevance of these processes. For these purposes, we have analyzed damage claim records of the PICB of Neuchâtel (NE), Fribourg (FR), Nidwalden (NW) and Graubünden (GR). These cantons approved our data enquiry and are chosen for this pilot study, as they cover different landscape patterns typical for the whole Switzerland.

TERMS AND DEFINITIONS

Terms used by scientists, insurers or practitioners to describe processes that can lead to water related damages to buildings may differ. Thus, hereafter, some important terms are defined:

- In accordance to the definition above, overland flow is understood as surface runoff that propagates unchannelled over the land surface until it reaches the next river or lake.
- Damages to buildings caused by water entering the structure at ground level (this excludes penetrating groundwater, backwater from the sewer system and rainfall directly entering the building through its envelope) are, hereafter, referred to as water damages.
- For reasons of readability, we abbreviate floods and inundations from rivers and lakes, explicitly excluding overland flow, by simply referring to inundations from watercourses. Thus, the term watercourse always refers to both rivers and lakes.
- In this paper, we make use of two different flood hazard maps (Swiss flood hazard maps and Aquaprotect, see methodology). The former includes assessment perimeters, whereas the latter does not. Both indicate areas that are at hazard complemented by hazard-free zones. All hazardous areas, regardless of the hazard level and the map source, are referred to as flood zones.

DATA

In Switzerland, PICB are present in 19 out of the total 26 cantons, within which they each hold a monopoly position. In addition, it is (with a few exceptions) mandatory for all house owners to insure their buildings against natural hazards including avalanches, snow pressure and -load, hail, storm, land- and rockslides, falling rocks and inundation processes. Concerning the latter, hazards associated with water entering the building at ground level are covered. Consequently, all damages caused by overland flow are insured and recorded by one single institution. Unfortunately, PICB generally do not distinguish different inundation causes and, thus, the responsible process for the claimed damages, namely overland flow or inundation from watercourses, must be identified.

DATA HARMONIZATION

For the present pilot study, we have analyzed records of house owners' damage claims related to flood processes of the PICB of Neuchâtel (NE), Fribourg (FR), Nidwalden (NW) and Graubünden (GR), representing the most typical landscapes of Switzerland. The data delivered by the different PICB were quite heterogeneous and, thus, needed to be harmonized. The most important variables used in this study were the address, geocode, total loss, processing status of the damage claim, as well as the occurrence date of the claimed damage:

- All four PICB provided geocoded damage claims. Claims with missing spatial reference were geocoded using the provided addresses, whenever possible.
- The loss of each damage claim was calculated by adding the payout and the corresponding deductible. Then, the losses were indexed to 2014. Note that in case of a covered damage, all PICB calculate the payout according to the reinstatement costs (value as new), except Fribourg. In the latter canton, reinstatement costs are determined according to (for us untraceable) depreciated values.
- The damage dates were checked for plausibility manually. The last year with complete records is 2013 for all four PICB. The complete records start in 1983 in Fribourg (31 y), 1987 in Nidwalden (27 y), 1988 in Neuchâtel (26 y) and 1991 in Graubünden (23 y), respectively.
- The status of the damage claims were categorized commonly. For this paper, only completed damage claims, i.e. claims with an actual payout, are considered. This ensures that only damage claims of an insured risk (i.e. overland flow and inundation from watercourses) are analyzed.

Overall, the data comprises 15'200 inundation related damage claims, of which 11'239 are justified and geocoded. For analyses concerning each canton separately (i.e. the compilation of percentiles, see methodology), the geocoded, justified claims are used. For the comparison between the cantons (i.e. number and total loss of the different classes per canton, see results), only the overlapping period from 1991 to 2013 is considered (23 y), counting a total of 9'451 damage claims.

METHODOLOGY

To differentiate damage claims that are associated either with overland flow or inundations from watercourses, we have developed a classification scheme (Figure 1). The scheme is not directly applicable to single damage claims, as it neglects important influencing factors such as micro and macro topography, the circumstances of a loss, etc. However, by applying it to a large dataset and computing summary statistics, the methodology is robust and produces productive results.

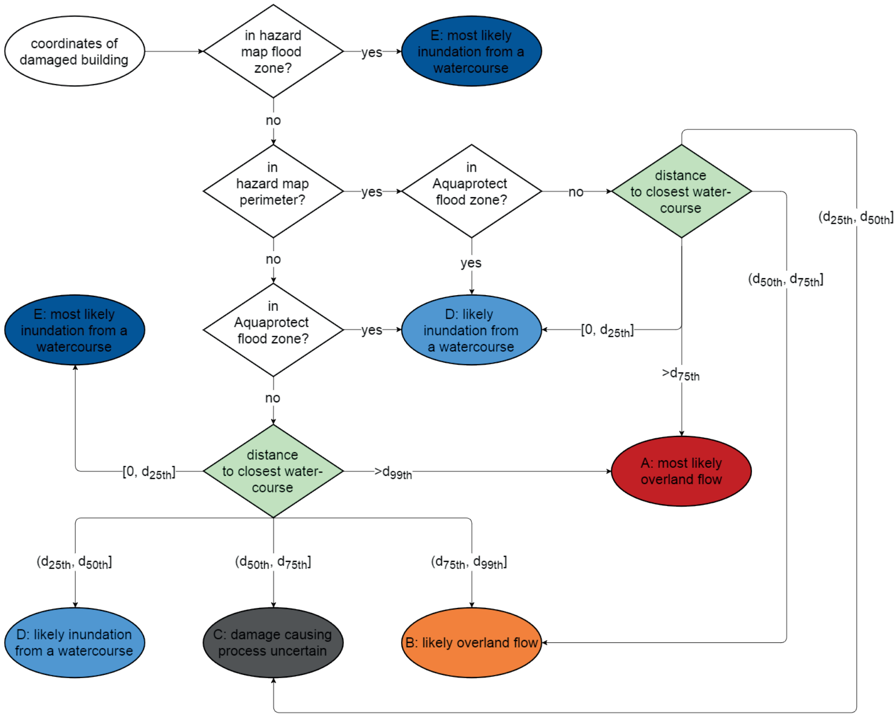

Figure 1: Each geocoded damage claim is categorized according to the displayed classification scheme. The white rhombuses each represents a yes or no test, checking whether the coordinates of the affected building are within 25 m of the corresponding spatial object (that takes the uncertainty of the buildings represented as point objects into account). Only coordinates located outside of the flood zones (hazard map and Aquaprotect) reach either of the green rhombuses. For each of these claims, the distance d between the claim's point location and the closest watercourse is compared to the 25th, 50th, 75th and the 99th percentiles of the corresponding cumulative distribution of the claims within flood zones (Figure 2, blue curve and percentiles). In this way, all claims outside of the flood zones are classified depending on the percentile range they fall in. All possible paths of the classification scheme are schematically shown in Figure 3 the colors of the ellipses are used throughout the paper to denote overland flow (A: red and B: orange), inundation from watercourses (E: dark blue and D: light blue) or damage claims that could not be associated with either process (C: gray).

The scheme makes use of existing flood hazard maps, as mentioned in the introduction. The rationale of the scheme is to use these maps directly for claims located within indicated flood zones. From this claim subset, we can then infer characteristics and use them for the classification of claims outside of the flood zones. For the latter claims, we make the following assumption: The distance to the closest watercourse from a flooded building determines how likely that particular building has been affected by inundation from a watercourse or by overland flow. Understandably, if the building is located close to a watercourse, the responsible process has most likely been inundation from that particular watercourse. On contrary, if the building is located far away from any watercourse, overland flow has most likely caused the damage.

The Swiss flood hazard maps provide detailed information about hazardous zones related to inundation from watercourses (Petrascheck and Loat, 1997). However, these maps were compiled for a predefined perimeter, which is generally constricted to construction zones. Moreover, the hazard maps were compiled with differing methodologies in each canton.
To smooth out these differences and to increase the spatial coverage, Aquaprotect, a flood zone map covering the whole Switzerland, provided by the Swiss Federal Office for the Environment (FOEN), is used in addition to the hazard maps. Assessed with a coarse but standardized methodology, Aquaprotect indicates flood zones of the larger watercourses associated with return periods of 50, 100, 250 and 500 years, while neglecting existing flood control measures. The dataset referring to a return period of 250 years is chosen, as the Swiss flood hazard maps consider a return period of maximal 300 years. Although it is possible that overland flow occurs within a mapped flood zone, it can be assumed that the predominant damage causing process in these areas are inundations from watercourses. Thus, the distribution of affected buildings located within flood zones in relation to the closest watercourse is used to classify damage claims located outside of these flood zones. Thereby we assume, that the patterns of damages caused by inundations from watercourses within the mapped flood zones are the same for damages located outside of these zones.
Clearly, the zone of influence of a watercourse depends on the geographical and geological properties of the landscape, as well as on the size of the river. For that reason, we compiled distance distributions for each canton and river size class separately. The latter is feasible, as the FOEN provides a dataset (referred to as FLOZ) that can be linked to the Swiss hydrological network of the product VECTOR25 provided by swisstopo. In that way, each river section is assigned to the corresponding Strahler Stream Order SSO (Strahler, 1964), which can be used as a proxy for the river's size. The SSO takes discrete numbers, which range from 1 to 9 in Switzerland. According to Weissmann et al. (2009) a SSO of 1 refers to small, 2-3 to medium and 4-9 to large Swiss rivers.
Figure 2 displays the cumulative distribution of the damage claims within or outside of the mapped flood zones, depending on the distance to the next river of a certain SSO. The blue curve, corresponding to the claims within the flood zones, rises sharply within the vicinity of watercourses but levels off quickly with increasing distance. On the other hand, the green curve, referring to damage claims outside the flood zones, rises more gradually and levels off at a much higher distance. We interpret this behavior as the superposition of damages caused by inundation from watercourses (small distances) and by overland flow (farther away from the watercourses). To obtain an objective way to disentangle these processes we take the distance to the next watercourse that correspond to the 25th, 50th, 75th and the 99th percentiles of the cumulated damage claims located within the flood zones (Figure 2).
As mentioned before, such curves are compiled for each canton and river class separately.

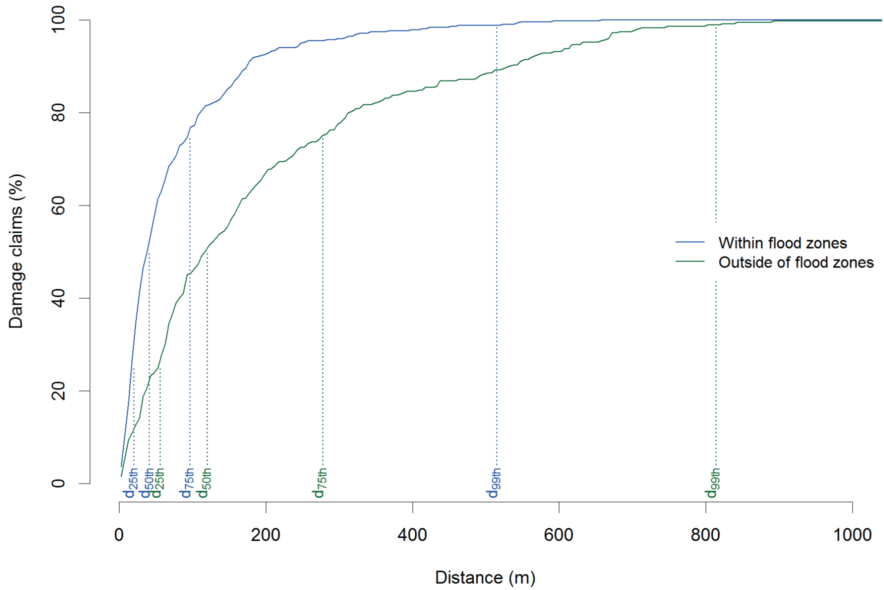

Figure 2: Exemplary cumulative distribution of all damage claims of Graubünden within flood zones that are closest to a medium sized river (SSO: 2-3), plotted against the distance to the corresponding river (blue curve). As a comparison, the cumulative distribution of all damages outside of the flood zones are displayed (green curve). Additionally, the corresponding percentiles (25th, 50th, 75th and 99th) of both curves are indicated (dotted lines). Note that for each of the three SSO classes (1-2: small rivers; 2-3: medium rivers; 4-9: large rivers) as well as for each canton, the percentiles of the claims within flood zones are computed and applied separately to reflect the different geographical and hydrological setting of each canton.

The coordinate pair of each damage claim is classified using the scheme shown in Figure 1. As a depiction thereof, all possible cases are illustrated in Figure 3. We distinguish five classes, each referring to the dominant process responsible for the claimed water damage with a qualitative indication of how certain the classification is:

- A: most likely overland flow
- B: likely overland flow
- C: damage causing process uncertain
- D: likely inundation from a watercourse
- E: most likely inundation from a watercourse

RESULTS

Our analyses show that 43 % of all claims are likely and most likely associated with overland flow and 47 % with inundations from watercourses (Figure 4). The remaining 10 % cannot be associated with either process. Looking at the numbers from the individual cantons, it becomes apparent that the fractions differ greatly from canton to canton. In Neuchâtel and Fribourg, more than half of the damage claims relate to overland flow. However, in Fribourg the classification is associated with a larger uncertainty, i.e. 18 % could not be classified as either overland flow or inundation from watercourses.

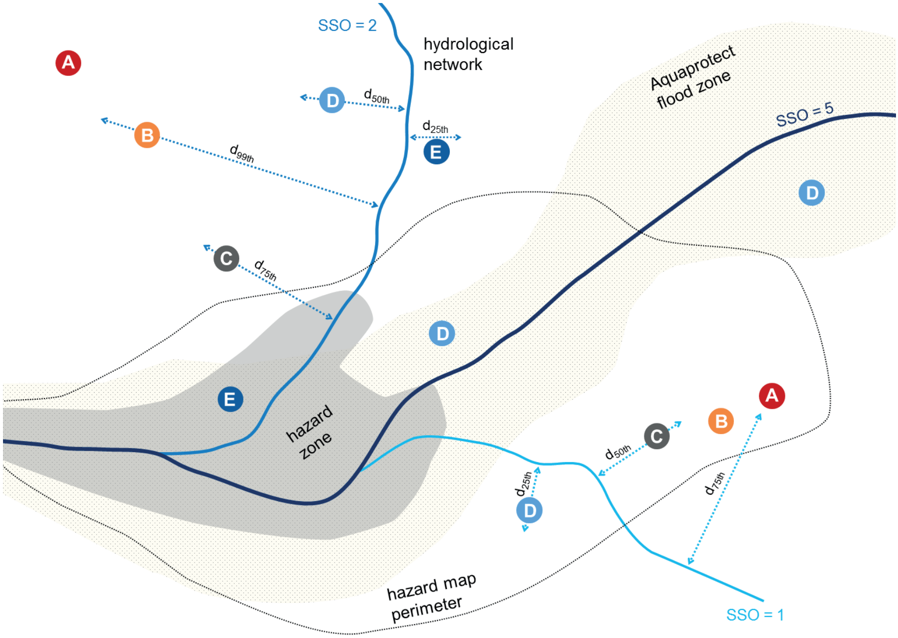

Figure 3: Each displayed point corresponds to a distinct path in the classification scheme (Figure 1) and denotes the corresponding process responsible for the caused damage (A: most likely overland flow; B: likely overland flow; C: damage causing process uncertain; D: likely inundation from a watercourse; E: most likely inundation from a watercourse). The arrows show how the percentiles of the cumulative distribution of damage claims within flood zones to the next watercourse are applied in practice. Furthermore, the display indicates that the percentiles are computed for each river class formed by the Strahler Stream Orders (SSO; 1-2: small rivers; 2-3: medium rivers; 4-9: large rivers) as well as for each canton separately.

In Graubünden 59 % of the claims are associated with inundation from watercourses, while more than every third claim relates to overland flow. The classification in Nidwalden shows a completely different picture. The vast share of 92 % of all claims is caused most likely by inundations from watercourses, while the remaining classes each account for only a few percent of all claims.

Although Nidwalden has the lowest amount of damage claims amongst the cantons in numbers, the total loss is almost as high as in Graubünden in the same period (Figure 4). The opposite is the case for Fribourg. It ranks highest amongst the cantons in terms of number of claims, but has a relatively low associated cumulated loss. Neuchâtel, although ranking in the same range as Nidwalden and Graubünden in terms of damage claim numbers, it had to cope with the smallest amount of loss.

To get an idea about the density of these processes in space and time, the numbers can be related to the size of each canton (Table 1). For this simple assessment, we have neglected the vulnerability, elements at risk and other possibly relevant factors: In Fribourg, damage claims are most frequently associated with overland flow and cause a yearly average loss of CHF 451.00 per km², followed by Neuchâtel. Although in Graubünden overland flow

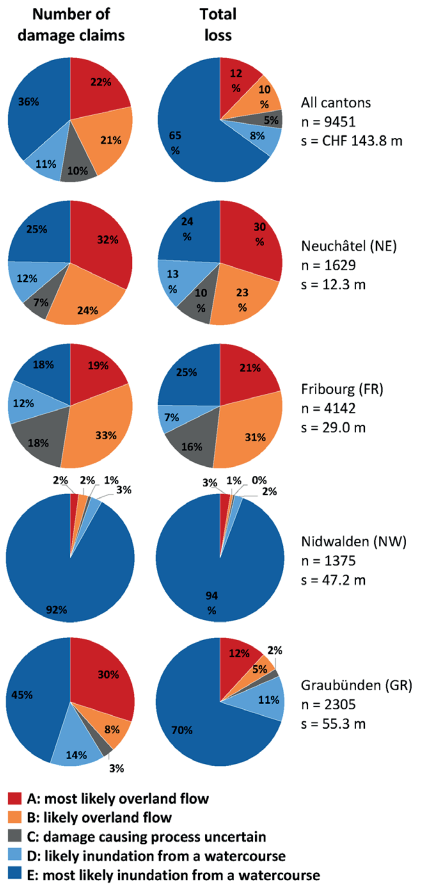

Figure 4: Relative distributions of the number of damage claims, as well as total water damage loss (indexed as per 2014) for each canton separately and for the cantons in total. Note that the number of claims (n) as well as the total loss (s) in million Swiss Francs correspond to the statistics of the overlapping period from 1991 to 2013.

accounts for almost 40 % of all damage claims (Figure 4) the density, both in terms of occurrence but also in terms of yearly loss per area, is by far the lowest. Graubünden also ranks last when looking at inundations from watercourses, however unlike the average occurrence of overland flow, the loss density is in the same order as in Fribourg, and Neuchâtel. Nidwalden, on the other hand, clearly stands out. With more than 0.2 damage claims amounting to more than 7000 CHF per km^2 and year, the values are by far the highest.

DISCUSSION

Based on several case studies, it is stated that about half of all (justified) water damage claims are caused by overland flow (e.g. Bezzola and Hegg, 2008). Our analyses based on gapless claim records of the last 23 years show that with 43 %, less than half of the claims can be associated clearly with overland flow. Nevertheless, the share is highly significant. In terms of loss, it also underlines previous case studies and assumptions respectively, revealing that on average, the loss associated with overland flow is lower than loss associated with inundation from watercourses. However, our results also show that this is not the case for all areas. The regional differences, as illustrated by Figure 4, can be explained by the different landscapes of the studied cantons. The geographical and geological patterns are reflected by the results:

– In Fribourg, representative for the Pre-Alps, overland flow occurs most frequently (Table 1), which can also be explained by the geological features, favoring overland flow (Weingartner, 1999). Further, the prevalence of many underground rivers that go partly back to extensive melioration in the past century promote overland flow. Inundation from watercourses are frequent as well, but less intense than in more alpine regions.

- As expected, in Neuchâtel with its typical karstic landscape, damage claims are more frequently caused by overland flow than by inundations from watercourses.
- Nidwalden, a canton with steep slopes, mostly less permeable soils, resulting in a dense river network, together with densely populated valley floors, is exposed heavily to inundation processes from watercourses (Figure 4). Although, overland flow may be responsible for certain damage claims, the dominant process is inundation from watercourses by far.
- Graubünden, the largest canton in Switzerland, is mountainous and overall loosely populated. Thus, the relative occurrence of claims related to inundations from watercourses, but even more so for overland flow, are very low. However, the associated losses are very high due to the devastating floods of mountain torrents.

Table 1: Yearly rates at which each canton is affected by overland flow (class A + B + ½ C) or inundation from watercourses (class ½ C + D + E, see also Figure 4), obtained by dividing the absolute numbers by the area of the respective canton and the record length of 23 years (1991 -2013). The rows are ordered according to the yearly rate of buildings affected by overland flow.

Canton	Area	Overland flow		Inundation from watercourses	
	(km^2)	($n/km^2/a$)	($CHF/km^2/a$)	($n/km^2/a$)	($CHF/km^2/a$)
FR	1'671	0.068	451.00	0.040	304.00
NE	803	0.053	382.00	0.035	282.00
NW	276	0.011	259.00	0.205	7'173.00
GR	7'105	0.006	59.00	0.008	279.00

CONCLUSIONS

Indubitably, overland flow causes frequent damages to buildings in Switzerland. For the first time, we can support this with a gapless data record covering representative areas of Switzerland, as we have collected and harmonized damage claim records of four Swiss PICB each representative for typical Swiss regions and covering the last 23 years. Due to the large dataset, the numbers are robust. However, it has to be noted that our novel methodology to disentangle water damages to buildings only works for large numbers and cannot be applied to single damage claims.

We have demonstrated that it is feasible and worthwhile to analyze damage claim data from public insurance companies, even more so, as it is, to our best knowledge, the only source that indicates overland flow over a large part of Switzerland within a longer period. The next step forward is to use the disentangled dataset, in order to analyze spatial and temporal patterns of the occurrence of overland flow. In this way, we can move towards more process-based investigations that are required to better understand and, ultimately predict, overland flow in the future.

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