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Severe historical floods on the river Roda, Thuringia: from reconstruction to implications for flood management

Mathias Deutsch[1], Tobias Reeh[2,], Daniel Karthe[3]*

[1] *Institute of Geography, project group "Environmental history", Georg-August-University of Göttingen, Goldschmidtstraße 5, 37077 Göttingen, Germany, amdeutsch@arcor.de*

[2] *Institute of Geography, Georg-August-University of Göttingen, Goldschmidtstraße 5, 37077 Göttingen, Germany, treeh@gwdg.de*

[3] *Environmental Engineering Section, German Mongolian Institute for Resources and Technology, 2nd khoroo, Nalaikh district, Ulaanbaatar, Mongolia, karthe@gmit.edu.mn*

[*] *Corresponding author*

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Abstract

Using the Roda river (Thuringia) as an example, we present methods for and results of historical flood research in Germany. The Roda river is one of the tributaries of the Saale river with a length of approximately 33 km. Although the watershed only covers around 262 km², the Roda is very vulnerable to flooding. The river caused damages of catastrophic dimensions within the urban area of Stadtroda (until 1925 "Roda"). These damages were especially devastating after heavy rainfall events during the late spring and early summer seasons of June 1582, April 1654, June 1827, June 1871 and June 1876. This article discusses how the flood history of the Roda river and human response to the associated natural hazards can be analysed by a combination of archive and field work. By means of the available material (e.g. printed, handwritten and physical sources as well as maps, engravings and historical photos), the history of severe floods was reconstructed for several centuries. This specifically refers to 1) the genesis, magnitude, frequency and length of floods, 2) the extent of damages and losses, 3) the risk perception and evaluation by municipal and national administrations and 4) the planning and implementation of protective measures and their impacts. Interestingly, the analysis of the disastrous floods of 1871 and 1876 shows striking similarities to the current discussion (e.g. regarding the influence of land use changes). Furthermore, the combined historical accounts are an important basis for the derivation of future flood risk assessments for the Roda river. Going beyond the specific basin of the Roda, the findings also reveal important insights regarding the impacts of increases in heavy regionalized rainfall for small watersheds, which is predicted to occur more frequently in such watersheds in the state of Thuringia.

Zusammenfassung

Anhand des Flusses Roda in Thüringen sollen exemplarisch Arbeitsmethoden und -ergebnisse der historischen Hochwasserforschung in Deutschland aufgezeigt werden. Die Roda ist ein ca. 33 km langer Nebenfluss der Saale im Saale-Holzland-Kreis. Obwohl die Einzugsgebietsgröße der Roda nur etwa 262 km² beträgt, ist sie ein stark hochwassergefährdetes Fließgewässer. Insbesondere nach Starkregen im hydrologischen Sommerhalbjahr ver-

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ursachte der Fluss vor allem im Stadtgebiet von Stadtroda (bis 1925: nur "Roda") katastrophale Schäden. Hierzu gehören beispielsweise die Ereignisse vom Juni 1582, April 1654, Juni 1827, Juni 1871 und Juni 1876. Vor diesem Hintergrund wird im Beitrag gezeigt, wie durch intensive Archiv- und Feldarbeiten die Hochwassergeschichte der Roda und der Umgang der Menschen mit dieser Naturgefahr analysiert werden kann. Ausgehend von der Vorstellung des verfügbaren Materials (z. B. gedruckte, handschriftliche und gegenständliche Quellen sowie Karten, Stiche und historische Fotos) können für einen langen Zeitraum unterschiedlichste Aussagen getroffen werden. Sie beziehen sich auf 1) die Genese und Auftrittshäufigkeiten schwerer Hochwasser, 2) das Ausmaß der Schäden und Verluste, 3) die Risikowahrnehmung und -bewertung durch kommunale und staatliche Verwaltungen sowie 4) auf Schutzmaßnahmen und ihre Wirksamkeit. Interessanterweise zeigen die Analysen der schweren Hochwasser von 1871 und 1876 Parallelen zu aktuellen Diskussionen (z. B. Einfluss der Landnutzung auf das Abflussgeschehen). Darüber hinaus können die Untersuchungsergebnisse eine wichtige Grundlage für die Erstellung von Hochwasserprognosen der Roda sein. Das ist insbesondere vor dem Hintergrund der auch für Thüringen vorhergesagten Zunahme regionaler Starkniederschläge in kleinen Einzugsgebieten von Bedeutung.

Keywords River Roda (Thuringia), severe historic floods, historical data, flood marks

1. Introduction

Floods are among the most destructive environmental disasters in Central Europe in terms of both human life and economic losses (*Osberghaus* 2017; *Herget* 2012; *Glaser* et al. 2010; *Brázdil* et al. 2005). The reconstruction of historical floods is therefore of large interest, aiming at the general estimation of flood risks, the design and operation of hydraulic and protective infrastructures, flood risk and emergency management planning and the calculation of flood insurance premiums (*Halbert* et al. 2016; *Deutsch* et al. 2015; *Kjeldsen* et al. 2014; *Deutsch* et al. 2010; *Mudelsee* et al. 2006; *Munzar* et al. 2005; *Pfister* and *Summermatter* 2004; *Deutsch* 2002; *Deutsch* and *Pörtge* 2001). It therefore remains an important field of work in modern hydrology (*Karthe* et al. 2017).

Different techniques are commonly used to investigate historical floods. During the 19th century, **instrumentation** such as gauges was installed in many German and Central European river basins, allowing for a quantitative assessment of floods (*Reeh* et al. 2015; *Deutsch* et al. 2000). However, for the early instrumental period, the accuracy of measurements is not always comparable to contemporary data (*Kjeldsen* et al. 2014; *Roggenkamp* and *Herget* 2014). For earlier floods, documentary evidence is an important source even though perception thresholds for severe floods changed over time (*Kjeldsen* et al. 2014). Besides information on the height and spatial extent of flooding, historical documents on meteorological conditions, water saturation in the catchment's soils and the socioeconomic implications of the flood are potential aspects addressed by historiographical research. Typical sources of such information include official documents, news reports, personal accounts and local historians' research (*Ruiz-Bellet* et al. 2015), albeit such accounts are often qualitative (*Roggenkamp* and *Herget* 2014). In case of unofficial reports as well as for photographs and paintings of unknown origin, it is important to verify the authenticity (*Wetter* et al. 2011; *Roggenkamp* and *Herget* 2014). **Flood marks** on buildings or bridges are another important information source for the reconstruction of historical floods, but labeling differs greatly (from none to the indication of years or even exact dates). One alternative for **palaeoflood reconstruction** (even beyond historical records) is the investigation of flood signatures such as specific sedimentary deposits (*Kjeldsen* et al. 2014). One common challenge with the interpretation of past data are environmental changes that have occurred, such as climatic changes, land use changes or hydraulic engineering (*Kjeldsen* et al. 2014; *Borrmann* 2010).

In historical terms, relatively flood-rich and flood-poor periods can be distinguished. This temporal clustering is strongly related to (regional to continental) climate variability and associated catchment memory effects (e.g. a prolonged water saturation of soils). For the Elbe river Basin, periods of maximum flood activity over the past 500 years include the late 16th century and the 19th century (*Glaser* et al. 2010; *Merz* et al. 2016). Continental climate induced floods occurred several times over the past few centuries. Across many parts of Europe, the 1870s (which are addressed by two case studies in this manuscript) were a period characterised by severe floods in vari-

ous river basins, ranging from extreme flash floods caused by intensive rainstorms on the Iberian peninsula (*Ruiz-Bellet* et al. 2015) to massive floods on the Elbe (*Elleder* 2010) and Rhine (*Wetter* et al. 2011). Using the Roda river as an example, we aimed at answering the questions (1) how did discharge events of extraordinary magnitude between 1500 and 1900 lead to river floods and (2) what triggered the two most extreme flooding events of the Roda river in 1871 and 1876.

2. Study area

The Roda river is a right tributary of the Saale river and originates at an elevation of about 385 m a.s.l., not far from Triptis, a small town in the present-day Saale-Holzland-Kreis (*Bauer* 2013: 174). After about 33 kilometres, the Roda river flows into the Saale river at an elevation of 149.5 m a.s.l., close to Jena-Lobeda (*Bauer* 2013; *Fig. 1*). The catchment area is only about 262 km² (*Bauer* 2013), which means that it can be easily covered by a major thunderstorm cell. Such a constellation is quite typical for hazardous flood events in Thuringia. The percentage of the area covered by coniferous forests is 50%. 25% of the drainage basin is covered with farmland and 17% is grassland (*Fischer* 2008: 63). The annual precipitation within the drainage area is around 600 mm (*Fischer* 2008). Significant tributaries of the Roda river are the Schwarzbach, the Weiherbach and the Zeitzbach. During the 19th and 20th centuries, parts of the Roda river were modified by hydroengineering, including measures such as the fortification of the river's banks as well as the expansion and deepening of the stream profile (*Photo 1*). According to the *Deutsches Gewässerkundliches Jahrbuch* ("German Hydrological Yearbook") (Elbe region, part I), there have been several severe floodings of the Roda river after 1950 (*LHW Sachsen-Anhalt* 2012: 167). Among other floodings, those of 4 June 1961 and 10 August 1981 caused extensive inundations (*Photo 2*). Most recently, a flooding of the Roda river during the end of May/beginning of June 2013 caused severe damages and losses in agricultural and inhabited areas.

Fig. 1 Map of the Roda's course. Source: Own elaboration (Department of Geography, Georg-August-University Göttingen)

Photo 1 View over the Roda river which was modified in the centre of Stadtroda during the 19th and 20th centuries. Photo credit: M. Deutsch 2012

Photo 2 Flooding of 10 August 1981 in Stadtroda near Münzbrücke. Source: Anonymous 1981, Town archive Stadtroda, folder "Natural Hazards", no sign.

3. Sources about historical flood events of the Roda river for the period 1500 to 1900

The sources mainly used for this study were handwritten manuscripts and documents. A large part of this material is stored in the town archive of Stadtroda as well as in the Thuringian state archive in Altenburg. Moreover, printed material from the 17th, 18th and 19th centuries was taken into consideration. This material is currently stored in the university libraries of Jena, Halle/S and Dresden. Furthermore, historical flood marks of the Roda river were gathered and used. Before further processing, all sources had to be examined critically. In order to clarify whether the handwritten manuscripts and documents in the chronicles describing the floods' courses were written at the time of the floods or whether the information was put down in writing years or even decades after the event, the different sources needed to be compared to other contemporary documents. Regarding this rather complicated aspect of historical flood research, the importance of considering as many primary sources as possible becomes apparent. Thus, the sources used for this article will be discussed in more detail in the following subsections.

3.1 Handwritten sources

Among other sources, letters by municipal authorities served as an important source of information. These letters report on the course of the different floods as well as on the extent of the damages (*Fig. 2*). Information on single fates was found in written petitions which were written by flood victims trying to receive financial support from the local government.

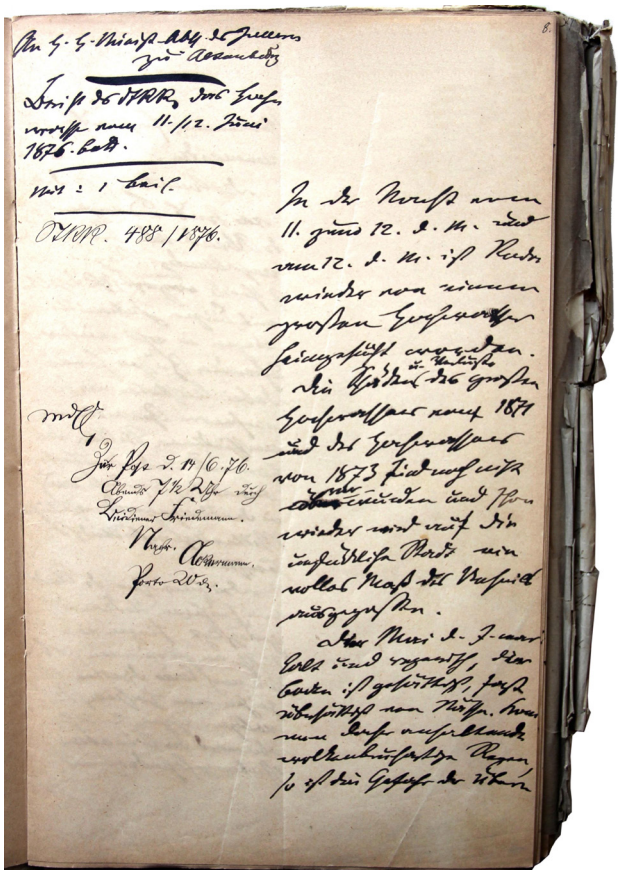

Fig. 2 First page of a written statement by the Roda city administration to the ministry of the interior (duchy Saxony-Altenburg) published on 14 June 1876 – flood report regarding 11/12 June 1876. Source: Anonymous 1876a, Town archive Stadtroda, Sign. I/ 2 B/ 131 G, page 8

"During the night of the 11th to 12th of this month, and on the 12th during the day, Roda has been hit by a great flood again. The damages and losses of the 1871 and 1873 floodings have not yet been overcome. And again, the hapless city has been struck by yet another misery.
This year's May had been cold and rainy, the soil was saturated, almost supersaturated by water. Thus, persistent and torrential rainfalls harbour the danger of causing severe floodings."

3.2 Printed sources

In addition to the handwritten sources, about 20 printed works were taken into consideration. Among these, the commemorate sermons regarding the severe floodings of the Roda in 1694 and 1827 turned out to be highly informative. Alongside theological contents, minute descriptions of the floods in June 1694 and June 1827 can be found in these texts. The

sermons were held only a few days after the events in Roda town and were printed shortly afterwards (*Crell* 1694; *Streicher* 1827). Besides these sermons, reports on floods in printed chronicles were of interest as well. One printed report from 1894 needs to be mentioned in particular (*Löbe* 1894). Furthermore, regional newspapers from the 19th century were made available for this study. Many articles concerning flooding were printed shortly after very severe flood events of the Roda river. These articles sometimes also included detailed eyewitness reports. At this point, it is important to note that some newspaper reporters dramatised the events or even printed false statements. For these reasons, the printed texts always had to be compared to handwritten primary sources.

3.3 Flood marks

In terms of flood marks (*Deutsch* and *Pörtge* 2009: 454), different material sources were preserved alongside the Roda river and its tributaries. In Stadtroda alone, two residential buildings and one former mill building provided flood marks which provided valuable information. The inscriptions impressively show the extremely high water levels of past floodings (*Photo 3*).

Photo 3 *Flood marks in the entrance area of the residential building Am Sand 2 in Stadtroda. Photo credit: M. Deutsch 2014*

4. Historical floods of the Roda river between 1500 and 1900

Throughout the course of this study, around 140 reports on floods (for the period 1500 to 1900) were gathered and evaluated. They include information about 36 historical flood events (*Table 1*). One can assume that all the listed cases of flooding caused more or less high damages and losses. Under no circumstances, these findings claim to include information on all floods that ever occurred at the Roda river. As other scientific studies from the Central German area show, the actual number of events is much higher (e.g. *Deutsch* and *Pörtge* 2017; *Reeh* et al. 2016; *Deutsch* et al. 2015). One reason for this would be that small floods that only caused minor or no damages at all are typically not mentioned in contemporary sources. Nevertheless, some of the listed events occurred in other watercourses on the territory of today's Free State of Thuringia as well (for example: 20 June 1694: Weiherbach, Zeitzbach; 10 June 1827: Weiherbach, Zeitzbach; 25/26 June 1871: Werra, Saale, Gera, Unstrut).

By the aid of the aforementioned archival sources, all 36 flood events were matched with a season (*Table 1*). It turned out that only two of the listed larger floods of the Roda river occurred during the six months of the hydrological winter (1 November to 30 April). These were the discharge events of April 1654 and April 1748 which were caused by continuous heavy rain. It seems noteworthy that none of the archival sources taken into account mentions severe winter floods caused by snow-melt. This is probably due to the relatively high percentage of forest cover in the catchment area, which buffers the runoff. 34 of the mentioned floods took place during the six months of the hydrological summer (1 May to 31 October). Within this time frame, most of the floods occurred in June (19 events). Moreover, there were six events of flooding reported for the month of May, five events in July, and four in August. In many cases, severe thunderstorms are reported to be the cause of flood events. Even if there are no available data concerning the contemporary precipitation sum, the archival sources indicate that large amounts of rainfall must have fallen within a very short time. In his work, which is fundamental for the area of investigation, *Bauer* (2013) suggests as well that severe floodings of the Roda river occur during the hydrological summer (especially from May to August) due to events of heavy rain.

*Table 1 Information on 36 flood events of the Roda river, which occurred between 1500 and 1900 and – according to documentation – caused damage and/or losses (in bold: 'major flood'; *: case studies discussed in Section 5). Source: Deutsch and Pörtge 2017: 80*

Century	Date	Reason for flooding	Remarks
16th	**1501, 25 July**	**severe weather**	**many bridges destroyed**
	1555, 2 June	-	barns washed away
	1573, 13 August	continuous rain	-
	1582, 29-30 June	**rain**	**many buildings damaged**
17th	1607, 23 June	heavy rainfall	-
	1618, 15 June	**continuous rain**	**mill buildings severely damaged**
	1619, 11 July	rain	meadows and fields damaged
	1654, 26 April	rain	extensive flooding
	1673, 24 June	severe weather	-
	1676, 6 July	-	high crop damage
	1694, 20 June	**severe thunderstorms**	**very severe damage and losses**
	1698, 18 May	continuous rain	bridges destroyed
	1698, 17 June	continuous rain	severe damage
18th	1702, 13 July	severe weather	-
	1707, 23 June	severe weather	many bridges destroyed
	1748, 22-25 April	**severe weather**	-
	1750, 24 June	severe thunderstorms	-
	1752, 1-3 August	**continuous rain**	**many footbridges destroyed**
	1754, 11 May	thunderstorms	residential buildings destroyed
	1755, 17 June	-	damaged premises
	1761, 24 May	thunderstorms	severe damage
	1761, 27 May	**thunderstorms**	**severe damage**
	1771, 29 June	**continuous rain**	**many bridges destroyed**
	1798, 1-3 June	**continuous rain**	**roads destroyed**
19th	1806, 22 May	thunderstorms	damaged fields
	1812, 16 June	rain	damaged fields
	1812, 4 July	rain	bridges damaged
	1812, 4 August	rain	-
	1812, 9 August	rain	-
	1816, 19 June	-	footbridges destroyed
	1827, 10 June	**severe weather**	**very severe damage**
	1827, 17 June	**severe weather**	**severe damage**
	1845, 30 May	**thunderstorms**	**mill buildings destroyed**
	1845, 7-8 June	thunderstorms	bridges damaged
	***1871, 25-26 June**	**rain**	**roads and paths destroyed**
	***1876, 11-12 June**	**rain**	**roads destroyed**

Regarding the 36 historical floods of the Roda river analysed, it is noteworthy that in some years, discharge events of extraordinary magnitude took place. For the years 1698, 1761, 1827 and 1845, two significant events of flooding were reported in each case. In 1812, there were even four larger floods: on 16 June, 4 July as well as on 4 and 8 August.

The question which of the floods of the Roda river during the time period from 1500 to 1900 can be classified as 'major flood events' – i.e. floods that were especially catastrophic – can only be answered indirectly. Due to the lack of alternatives, the damage patterns need to be taken into account, even though they are not a direct indicator for flood magnitudes (cf. Rhine

river floods 1993/1995). There is extensive information about very severe floods in the local chronicles. After all, these events were 'unheard-of incidents' that were of crucial significance to the residents and therefore made an impact on regional historiography. 14 floods of the Roda river can be classified as particularly severe and their impacts declared as catastrophic (bold in *Table 1*). The data show that most of the catastrophic flood events took place in the month of June (a total of seven events). Which one of the 14 listed floods was the most severe event during the assessment period (1500 to 1900) remains questionable, as this aspect cannot be fully answered by the available sources.

The scopes and limits of historical sources for reconstructing hydrological extreme events of the past are discussed in more detail in two case studies: the Roda floodings in 1871 and 1876. Not only did the two events both take place before discharge and gauge height were measured and are hence dependent on historical flood research, but they also took place during a decade of severe floodings in many other parts of Europe (see above).

5. Case studies of severe historical Roda-floodings

5.1 The flood of 25 and 26 June 1871

5.1.1 Initial conditions

According to a Stadtroda town chronicle, there had been continuous rainfall several days prior to the flood (*Löbe* 1894: 131). This is confirmed by reports of the daily press. As a result, the soil moisture had reached the greatest possible extent. When large amounts of rainfall fell on the 25 of June 1871, no more moisture could be absorbed (*Löbe* 1894) and a catastrophic flooding was imminent.

5.1.2 The flood's course

Even though there had been heavy rainfall on 25 June during the day, the Roda river had risen only marginally by the end of the day (*Löbe* 1894). It was not until 12 a.m. that the river had transgressed its banks. Until the early morning of 26 June (after 4 a.m.), the water level rose continuously and then remained the same for around one hour (*Anonymous* 1871a). According to a contemporary report, at that time, the Roda's waterline came to approximately 2.83 m above the mean level. Vast areas close to the river, among them Stadtroda, were inundated. At around 5 a.m., the water slowly began to go back down (*Anonymous* 1871a). In the course of the next few hours, the water pulled back entirely from inhabited areas.

5.1.3 Damages and losses

All in all, the damages can be classified as catastrophic. In most of the villages and townships adjacent to the river, the water had severely damaged both private and municipal property. Among the damaged property were, for instance, bridges and landing stages, residential and business premises etc. (*Anonymous* 1871b: 769; *Anonymous* 1871a). Stadtroda was left with heaps of sand, stones, and scree in many streets and alleys. These deposits reached up to 2.26 m in height. According to contemporary reports, this flood was declared to be the most severe flood of the 19th century. The aforementioned reports emphasise that during the event, the water was up to 4 to 5 inches (approx. 9.5 cm to 12 cm) higher than it was during the floods in 1827 and 1845 (*Anonymous* 1871a).

5.2 The flood of 11 and 12 June 1876

5.2.1 Initial conditions

According to a contemporary report, the soil in the Roda catchment area was nearly saturated with water after the winter of 1875/1876 due to high precipitation (*Anonymous* 1876b: 240). In 1876, the month of May was still cold and wet which is why the soil had no opportunity to dry off. Instead, the soil moisture increased because of further precipitation (*Anonymous* 1876a: 8). Only the Whit Sunday of the year (which was the 4 June) was a nice and sunny day. Afterwards, however, it soon started to rain again (*Anonymous* 1876b: 240). According to the descriptions in one of Roda's town chronicles, there had been several rainy days before a destructive flooding occurred (*Löbe* 1894: 133). Sunday, 11 June 1876, was a cloudy as well as rainy day. In the evening at around 9 p.m., continuous rainfall started. Several different contemporary reports even mention thunderstorms that included heavy precipitation (*Anonymous* 1876a: 8^{R}).

5.2.2 The flood's course

Even though the Roda's water level and that of its tributaries had already been high on 11 June 1876, the residents did not see a threat in that. It was only when the water level rose up further during the evening hours that, at around 12 a.m., extensive safety measures were initiated (*Anonymous* 1876a: 8^R). As a precaution, residents along the river emptied the rooms in the lower levels of buildings (*Anonymous* 1876c). On 12 June 1876, at around 2 a.m., the flood reached its climax. In the town of Roda, municipal authorities mobilised all available fire brigades. In addition, footbridges leading across the Roda river were secured with ropes to prevent them from being washed away. Eventually, vast areas of the Roda valley were flooded on 12 June between 2 and 3 a.m. According to reports from the town centre of Roda, water ran through numerous streets and alleys from 3 a.m. onwards. Among other things, the river carried along fences, boards and tree trunks. A newspaper article describes the flood's course as follows: "for more than three hours, the water level remained very high. At 7 a.m., it began to decrease a little, but only half an hour later [at around 7:30 a.m.] it rose even higher because of continuous rain. The water rose with power…" (*Anonymous* 1876c, translation by the authors). People living in the villages and townships along the river had to be rescued from their homes and animals brought out of their stables. Finally, on 12 June at around 11 a.m., the water level went down a little, only to rise back up again about one hour later. In parts of Stadtroda, the water level even rose up to 1.70 m. Not only wooden bridges were destroyed during the flood, but also solid bridges made of steel or brick work. Eventually, at around 4 p.m., the water level slowly went down. The residents however, still feared an additional rise since it was still raining at that time. As it turned out, these fears were unfounded. In the early evening of 12 June 1876, the flood wave had passed the urban area of Roda (*Anonymous* 1876a: 10^R).

5.2.3 Damages and losses

According to reports, the damage of roads in numerous villages and townships was not as severe as after the catastrophic flood in 1871 (see above). Nonetheless, several buildings alongside the river (among them residential as well as business premises, sheds, stables, etc.) had suffered severe damage. What is more is that the flood had washed away many bridges and landing stages. It seems noteworthy that the damages caused to buildings during the flood of 1876 were higher than after the flood in June 1871. One reason could be that in 1871, the water went down again comparatively quickly. During the flood in 1876, however, the water remained at least 15 to 16 hours in the lower levels of the buildings in the town of Roda. Some parts of the buildings – among them, for example, the floorboards – were demolished entirely (*Anonymous* 1876a: 12).

5.2.4 Contemporary remarks regarding the causes of the 1876-flood

In the course of this article's material research, one newspaper article from 1876 dealing with the causes of the flood was analysed (*Anonymous* 1876b: 240). It was published only a few days after the event in the "Altenburger Zeitung". Its essential messages are reported here. From the anonymous author's point of view, two factors had a crucial impact on the course of the flood in June 1876:

a) The increasing deforestation in the Roda's catchment area and
b) the installation of drainage ditches.

While the article does not provide any further explanatory comments on point a), the author deals with point b) in great depth. According to the article, the installation of numerous drainage ditches in the Roda's catchment area had taken place during the years preceding the flood. These ditches were supposed to withdraw excess water from the soil and thus discharge the water as quickly as possible into the valley or the Roda river. It is not mentioned to what extent these construction measures had a positive effect on the soil itself and thus on the state of the forests. The author does, on the other hand, critically mention another effect of the new drainage ditches. Especially in the event of heavy rainfall, a large part of the water is not being retained by forest soil anymore. Therefore, it cannot flow off slowly like before but enters small tributaries and the Roda river's main channel within a short time. As a consequence, the river's peak discharge is much higher, which is problematic in the event of flooding. The author did not offer any specific recommendations that would change the contemporary conditions. He did, however, state that 'measures' had to be taken to decelerate the water's fast discharge. Finally, it needs to be emphasised that this

example demonstrates how, even in the second half of the 19th century, the negative impacts of drainage measures were perceived and modifications demanded (see also *Schmidt* 2000). Thus, currently requested measures that intend to keep the water within the soil as long as possible, are certainly not new.

6. Discussion

For this study, information on 36 severe flood events that occurred between 1500 and 1900 on the Roda river was gathered. For this purpose, handwritten and printed manuscripts were analysed and historical flood marks examined. Precise statements regarding the exact time of the events as well as their causes were made depending on the available historical descriptive sources. Furthermore, 14 events were identified as very severe or catastrophic based on the reported claims.

In the course of the centuries, the number of flood events fluctuated. Based on the historical sources, it can be summarized that severe floods mainly occurred during the hydrological summer months. According to contemporary reports, heavy and continuous rainfall was identified as the main reason for these severe floods. However, a clear ranking of the floods is not possible based on the available sources.

Despite of all limitations, the waterlines of the two flood events presented as case studies could be estimated by means of hydraulic modeling (*Thiele* and *Büttner GbR* 2015). Based on the results arising from 2D-modeling, a peak discharge of 114 m^3/s was generated for the event in June 1871 and 109 m^3/s for the event in June 1876 (*Thiele* and *Büttner GbR* 2015: 17). A precipitation of 134 mm in 24 h resulted in the peak discharge of the 1871-event. The recurrence interval of this amount of precipitation is 1000 years (*Thiele* and *Büttner GbR* 2015: 32). This underlines the fact that hydraulic structures which were put up over the centuries, did not manage to entirely eliminate flood risks. Regarding extreme events in inhabited areas, discharge cannot be controlled by economically justifiable flood protection.

Nonetheless, these outcomes offer possibilities to improve flood predictions for the Roda river. This aspect is especially vital regarding the predicted increase in regional heavy rain (*Schönwiese* 2007; *Kappas* 2009) in small watersheds in Thuringia. To expand the length of the investigated period and thus improve the empirical basis, in the future it is necessary to further investigate

(1) flood marks that were verifiably not readjusted due to the modification of buildings or for other reasons;
(2) the existence of sufficiently proofed and preferably original sources (with detailed descriptions of sequences of prominent floods but also information on channel changes nearby flood marks or damaged buildings/infrastructure);
(3) records concerning hydraulic structures in archives (if possible, with an assessment of their relevance for water levels and discharge).

Additionally, hydrological modeling of past discharge events could help to better understand their dynamics.

All in all, the consideration of a longer time frame offers a more reliable image concerning flood events. "The [...] opinion, that populated areas would be absolutely protected from floods by [...] technical constructions, is fallacious and dangerous" (*Reeh* et al. 2016: 82). Instead, the handling of floods must be even more sensitive, especially regarding historical flood events (e.g. *Deutsch* and *Pörtge* 2017; *Reeh* et al. 2016). Here, limits of technical systems should be recognised and potential damages prevented (*DKKV* 2015: 187-188). Therefore, a reinforced publicity effect on risk communication is necessary (cf. *Deutsch* and *Pörtge* 2007). It is important to keep the general public alert to the dangers of floods and not to dismiss experiences made during past floods when discussing current decisions (e.g. the designation of building land, flood protection for domestic technology with regard to reconstructions or refurbishment). Even if a stream or a river does not pose a threat to residents over a long period of time, it is possible that it may turn into an immediate danger after severe rainfall, despite existing precautionary measurements like storage basins or dikes (*Reeh* et al. 2016). "Thereby, potential catastrophic scenarios can be demonstrated based on past flood events" (*Reeh* et al. 2016: 82).

7. Conclusions

A river development strategy which includes flood protection for the river Roda and its tributaries is currently being planned in the scope of the Thur-

ingian state programme for water conservation (see *Thüringer Aufbaubank* 2017). It is supposed to consider historical flood research systematically for the first time. The project's sponsors realised that the initial channel relations, the former expansion of floodplains as well as flood history need to be taken into consideration in the definition of development objectives as well as in the establishment of specific flood protection measures. Special attention is paid to information regarding the floods' course, expansion and intensity, including damage focusses. This is remarkable in so far as this approach has not been executed consequently in the Free State of Thuringia before. The article at hand is considered as part of this pilot project – even if more archive research is definitely necessary in order to contribute meaningful planning documents (including as detailed cartographic representation as possible) from the perspective of environmental history.

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