Hydrometeorological extremes and their impacts in the Jihlava region (Czech Republic) in the 1650–1880 period

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Introduction

Disastrous floods, hailstorms, droughts and other hydrometeorological extremes (HMEs) have a significant influence on human lives. The study presents reconstructed HMEs based on different documentary evidence and secondary sources in the Jihlava region (central part of the Czech Republic - **Fig. 1**) during the 1650–1880 period. The paper analyses spatiotemporal distribution of HMEs and presents assessment of the impacts of HMEs with regard to physical-geographical characteristic of the area studied. Results are discussed with respect to uncertainties associated with documentary evidence.

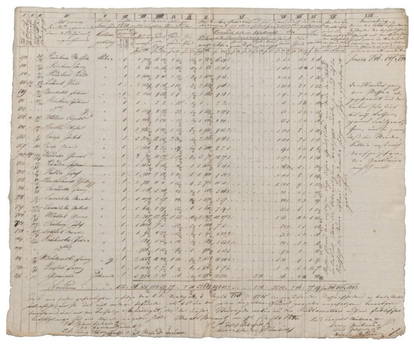

Fig. 2 *Taxation record relating to damage caused by hailstorm on 27th August 1845 in Kamenice (S1)*

Fig. 3 *Hailstorm insurance report from Třešť written on 27th May 1876 (S2)*

Fig. 4 *Front page of Prager Zeitung published on 26th August 1816 (S3)*

Data and methods

Different types of documentary evidence allow derive information related to HMEs, their spatiotemporal variability and human impacts. Economic records (taxation and damage records - **Fig. 2**, decisions of tax relief, insurance reports - **Fig. 3**; etc.), narrative sources (annals, chronicles, memory books), official correspondence and special prints present the basic data sources used. Many of these records were hand-written in neo-Gothic italic script in German (in more recent times also in Czech). The information related to HMEs was carefully transliterated and excerpted and the database of HMEs was created. Documentary evidence was complemented by secondary sources (early newspapers - **Fig. 4**, published narrative sources, scientific papers etc.) (**Fig. 5**). Where possible, individual records were checked by cross-referencing to other evidence and the same HMEs were included. Individual events, dates of occurrence, settlements affected, the type of damage and source of data became the basic information for further critical analyses and interpretations.

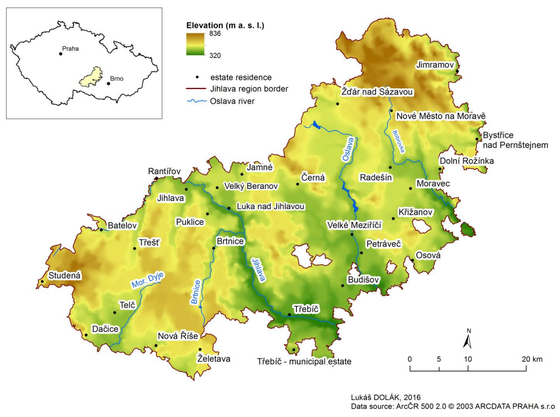

Fig. 1 *Area studied with the historical estates residence*

Results

Frequency of HMEs

Based on the documentary evidence and secondary sources for 29 estates, 510 events were identified between 1650 and 1880. HMEs were attributed to 11 different types of extremes, such as hailstorm (23.3%), torrential rain (17.9%), thunderstorm (13.5%), inundation (9.4%), flash flood (8.1%), frost (6.6%), windstorm (including tornadoes, 6.4%), lightning strike (causing death, injury, fire or other damage, 5.4%), drought (3.6%), blizzard (2.9%) and flood (2.9%). Types of HME were divided to short-term events (associated with convection, eight types) and long-term events (lasting for several days/months, three types). The frequency of HMEs was expressed both by individual event (**Fig. 6a,b**) and type of extreme (**Fig. 6c**).

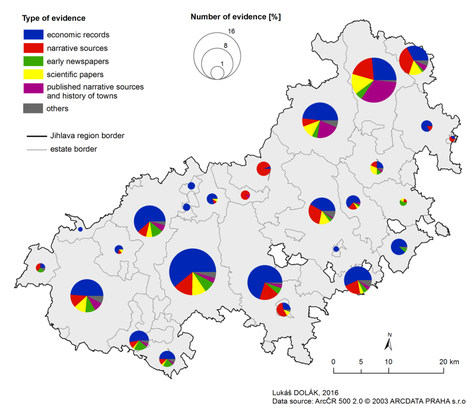

Fig. 5 *Type and number of evidence [%] for every estate*

Spatiotemporal distribution of HMEs

HMEs detected were concentrated mainly in the 1750s and from the 1790s to the late 1840s. The mean annual number of HMEs during 1650–1880 period (231 years) counts 2.2 events. However, HMEs were recorded only during 168 years, i.e. 3.0 events per year in average. The maximum of HMEs per one year was recorded in 1830 (14 events). In terms of their annual distribution, June (20.2%) was followed by July (16.7%), August (15.5%) and May (14.1%), i.e. 66.5% of all events occurred in four months. Concerning the seasonal distribution of HMEs, summer (57.6%) was followed by spring (24.2%), winter (12.8%) and autumn (5.4%). The highest frequency of individual events (15.4%) was recorded on the Brtnice estate (the central part of the Jihlava region) (**Fig. 7**).

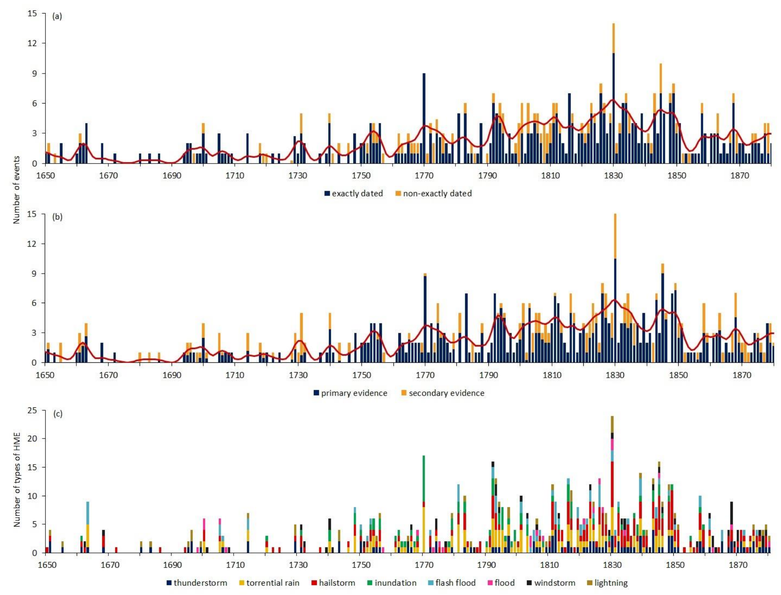

Fig. 6 *Annual frequency of total HME events according to (a) exactly/non-exactly dated events and (b) primary/secondary evidence smoothed by Gaussian filter for 10 years and (c) individually classified types of short-term HME*

Severe storms and hailstorms

In total, 32 events (6.3%) were classified as severe storms (**Fig. 8**) represented by hails ≥ 2 cm (78.1% cases), windstorms with wind speed ≥ 25 m.s^{-1} (12.5%), tornadoes (6.3%) and in one case by hail and tornado (3.1%). Severe storms caused damage in 50 villages.

Hailstorms accompanied 39.8% of all events and 286 villages reported damages by hail. In the Jihlava region was recorded 52.2% of hail days in comparison with the rest of South Moravia (47.8%) in the 1811–1850 period (**Fig. 9**). About 8% more hail days in the 1811–1850 period than in the years 1961–2000 occurred in average in the Jihlava region (**Fig. 10**).

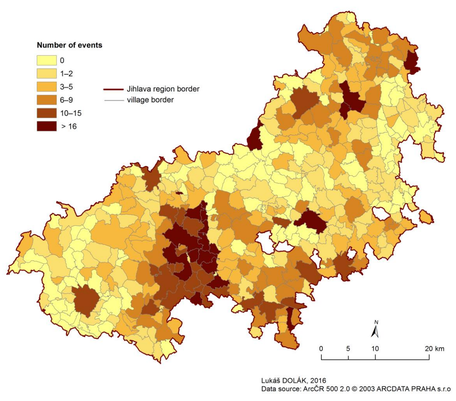

Fig. 7 *Spatial distribution of total HME events in the Jihlava region during the 1650–1880 period*

Impacts of HMEs

- **Impacts on agriculture and crop production:**
  - fields and crops: damaged crop, fruits, trees, deposits of sediments, soil erosion, frozen or withered plants
  - meadows and pastures: inundation, sedimentation, damaged grass/hay
  - livestock: loss of livestock, injuries, starving, diseases
- **Impacts on material property:** destroyed houses, farm buildings, domestic equipment, roads, squares, bridges, river banks, pond dikes, broken windows, roofs, burnt harvest and fodder
- **Socio-economic impacts:** indebtedness, incapability to pay taxes, decrease of quality of life, lower investments in farming (**Fig. 11**)

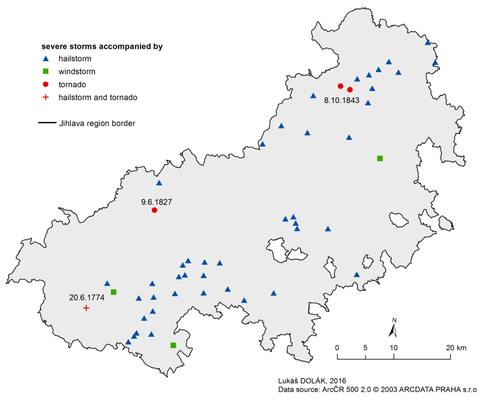

Fig. 8 *Spatial distribution of villages and towns affected by severe storms*

Discussion

Results obtained can be slightly influence by uncertainties related to:

- incomplete documentary evidence for some estates (influencing spatiotemporal distribution of HMEs)
- annual distribution of HME reports with predominance for summer months (JJA)
- inaccurate or wrong dating of some HMEs
- uncertainty in the type of HMEs

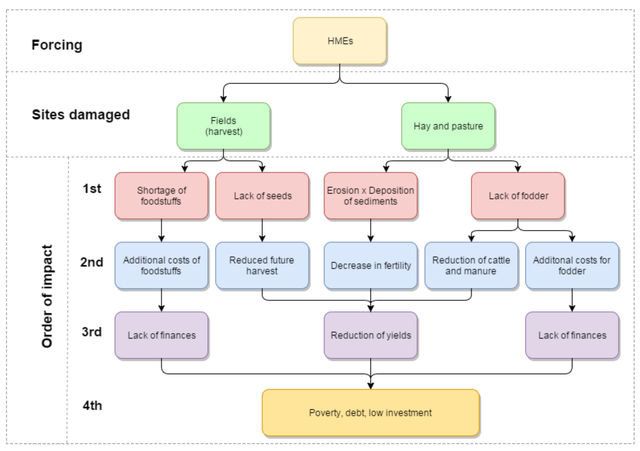

Fig. 11 *A model of hydrometeorological extremes impacts on fields and meadows (Dolák et al., Geografie, 2015)*

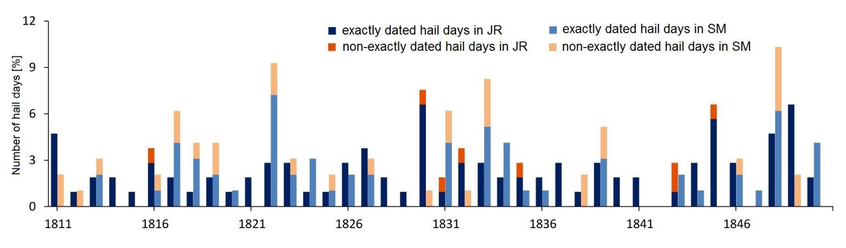

Fig. 9 *Comparison of relative annual distribution of hail days [%] in the Jihlava region (JR) and South Moravia (SM; without JR) in the 1811–1850 period (modified on the base of Brázdil et al., TAC, 2014)*

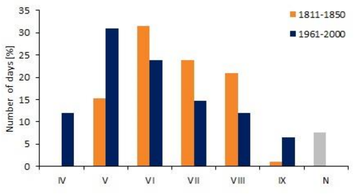

Fig. 10 *Comparison of relative annual distribution of hail days [%] in summer half-year in the Jihlava region in the 1811–1850 and 1961–2000 periods (N – non-dated event in JR*

Conclusions

The paper demonstrated spatiotemporal distribution of 510 HMEs in the Jihlava region during the 1650–1880 period and described impacts of HMEs at the regional/local level. Documentary evidence creates a unique source of HMEs data contributing to the better understanding of past HMEs and their impacts in the pre-instrumental period. The knowledge of past HMEs in combination with the data from instrumental measurements may be used in current risk management and it can reduce potential hazards.

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S3 Prager Zeitung, No. 239, 26th August 1816, p. 949.