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HEAVY RAINS AND FLOODS IN EUROPE DURING LAST MILLENNIUM

Abstract: The information on heavy rains and floods during the last millennium are based on records of various qualitative and quantitative precision starting from direct measurements to historical written sources and proxy data based on sediments, organic remains and relief features. Among these extremes there were distinguished heavy downpours, continuous rains, rainy seasons and rapid snowmelts. The author describes the course of phases with higher and lower frequency of extreme rains and floods in Europe, regionally differentiated. The phase of the Little Ice Age is well expressed throughout the Europe, although the particular events were never simultaneous. Finally follows the discussion on causes of these variabilities in space and time.

Key words: extreme rains, geoecosystems, floods, Europe, last millennium.

1. Introduction

Extensive deforestation and cultivation combined with population growth and developing cities, later followed by industrialisation and finally by organised water management create fascinating scenery for the study of the role of heavy rains and floods in the transformation of geoecosystems during the last millennium. The varying frequency of heavy rains and accelerated runoff facilitated the passing of thresholds of various natural systems with frequency fluctuating from century to century and from decade to decade.

2. Sources of Information

Last millennium offers a great variety of records of different qualitative recognition, quantitative precision and definite localisation in space and in time. Three main groups should be distinguished among them:

1. Direct rainfall and hydrological records

These include instrumental records of precipitation rarely starting before 19th century, measurements of water stages on larger rivers, markers of high flood water levels on buildings upon river banks as well as maps and photos showing the extent of flooded areas or extent of damages left by floods (Brazdil et al. 1999).

2. Indirect records

These data are less quantitative as well as less precise in space or time. Among them there are various written sources on heavy downpours, continuous rains, ice jams and floods related to river valley, region and sometime to a single town or village. There are also drawings and pictures describing flood events as well as, starting from 17th century, the plans or maps of surveyed river channels and river banks after extreme events (Brazdil et al. 1999).

3. Proxy data

This large group of data include different geological and geomorphological records which by use of retradiction procedure make possible to reconstruct sometimes very precisely the type and extend of single flood, the course of erosion or deposition and at least to distinguish phases with various flood frequency. Of greatest importance are sediments of various facies: alluvial (among them channel, levee, crevasse backswamp and other sediments), colluvial, proluvial, deluvial etc., including organic remains, as well as forms created during heavy rains and floods like gullies, landslides, debris flows, undercut scarps, abandoned river channels etc. All of them may be dated more less precisely by ^{14}C, ^{210}Pb, ^{137}Cs and other radionuclids or by various archaeological methods usually as „antequem" or „postquem" in relation to organic or cultural horizons (Starkel et al. 1991). The phases with higher frequency of extreme events may be well identified by clusterings of subfossil oak trunks, frequent heavy rains can be also recognised by higher rates of peat growth and by rising lake water level (Ralska-Jasiewiczowa, Starkel 1988).

3. Types of Extreme Rains and Floods

In the climatic conditions of Europe several types of extreme events can be distinguished. Each of them may be more or less precisely expressed in deposits and forms. Depending on that we can draw conclusion on the spatial and temporal extend of events (Starkel 1976, 1994).

1. Heavy downpours are restricted to areas of several or several tens of sq. km. The rainfall totals fluctuate between 20 and 150 mm but their intensity exceeds 1-3 mm per minute. Such rains create in the tree-less areas an intensive overland flow, wash over slopes and conditions for the debris flows and flash floods.

2. Continuous rains cover extensive areas of many thousands of sq. km and in spite of low intensity, due to a long duration and high rainfall totals (reaching 300-600 mm) they facilitate an infiltration in the ground, the subsurface runoff with piping, landsliding and finally the formation of flood waves in larger catchments. The 1997 flood in the Oder basin may serve as the example. The greatest damages are connected with the heavy downpours superimposed on the continuous rain, when simultaneously

the thresholds of slope and river channel runoff as well as sediment load including mass movements are passed (Froehlich, Starkel 1994).

3. The opposite extremes (in relation to downpours) are rainy seasons when during several rainy months the groundwater storage is close to 100% and very intensive rainfall or snowmelt may cause the reactivation of landslides and flooding (Gil, Starkel 1979).

4. A specific features for the more eastern and northern Europe (as well as for the mountain areas) are the rapid snowmelt floods, accelerated frequently by simultaneous rain and/or following after cold weather with frozen ground (Starkel 1976). In the valleys with rivers flowing towards north these floods are combined with the formation of ice jams, which during the Little Ice Age were recorded also from more southern regions.

4. Regional Differentiation of Heavy Rains and Floods over Europe

The studies on frequency and extend of heavy rains and floods are mainly restricted to the western and central part of Europe or to mountain areas. In the European scale we observe a great variety from the Mediterranean to subarctic areas and from the oceanic climate in the west to continental one in the east (Parde 1933; Sundborg, Jansson 1991). In the S-N transect the Mediterranean winter rainy and snow-melt floods are replaced in the Central-European mountain basins by more frequent summer rainy floods although even there, in the lowland basins, the spring mixed floods are prevailing. In the north with the reducing effect of the postglacial transfluent lakes the floods are rare and restricted to spring breaking of ice. The western edge of Europe is exposed to humid air masses and winter continuous rains are the leading factors. On the contrary, in the East-European plains the seasonally frozen ground and continuous snow cover during rapid melting prefers the spring flooding combined with ice jams (Lvovich 1971). This brief regional division does not mean that there exist sharp boundaries especially in the transitional zone of Central Europe with great variety of winter and summer seasons and vertical diversity of precipitation. Just the opposite, we can expect various types of floods, like the last spring flood of 2000 in Transylvania and Hungary caused by a rapid snowmelt combined with heavy rains.

5. Changes of Heavy Rains and Floods during Last Millennium

The examination of extreme events over Europe during the last millennium is based on very unequal information, more detailed for the selected catchments in SW and NW as well as in Central Europe (Bradley, Jones 1992; Brazdil et al. 1999). The information from more eastern countries is not so widely propagated (Schwetz 1978; Maruszczak 1988). During the last millennium there may be distinguished several longer or shorter episodes with higher frequency of different extreme events, well recognised by their clusterings (Starkel 1998). These variations usually are discussed

jointly with general fluctuations in temperature and humidity (Lamb 1977; Grove 1988; Pfister et al. 1998). Due to extensive deforestation and cultivation the sedimentological records show an acceleration of soil erosion and sediment load which coincide with the Little Ice Age (Starkel 1994).

The first three centuries are usually presented as the Medieval warming (Lamb 1977), but at least 11th century was humid. This was stated only in Britain where growth rate of the Bolton Fell Moss increased (Lamb 1984). After Pfister et al. (1998) between 1090 and 1180 AD a distinct drop in temperature was recorded. At several localities in the Middle Europe the organic horizons or cultural layers of 10th and early 11th century are buried under thick alluvial or proluvial loams (Radwański 1972; Niedziałkowska et al. 1985; Jersak et al. 1992; Starkel 1994; Havlicek 1980) as well as there are buried oak trunks with distinct clusters at 1020-1030 AD and 1075-1100 AD (Krąpiec 1992; Starkel et al. 1996). Next two centuries (12-13th) were drier in Britain and Germany due to the blocking of western zonal flow (Lamb 1984), but on the contrary in the Dnieper valley from 1100-1250 AD higher discharges were recorded (Schwetz 1978), in western Spain floods were frequent between 1150 and 1290 AD (Benito et al. 1998), in central Italy lake water levels rose (Dragoni 1998).

The transition to the main Little Ice Age (1300-1550 AD - following Flohn 1983) shows again some rise in the flood frequency reported from Spain in 15th century (Benito et al. 1998), Italy (Pavese et al. 1996), Ukraine (Schwetz 1978). In Britain the reactivation in transformation of river channels is explained by higher activity in that transitional phase to the Little Ice Age (Rumsby, Macklin 1996). With the period 1250-1400 AD several dated landslides in the Polish Flysch Carpathians coincide (Alexandrowicz 1996) indicating probably the long lasting rainy seasons.

The monographic study of 16th century floods by Brazdil et al. (1999) supplemented by records from Poland (Strupczewski, Girguś 1965; Czerwiński 1991), Spain (Benito et al. 1996), Russia (Lyakhov 1988) and Ukraine (Schwetz 1978) delivers a very interesting picture. In every catchment the clusterings of several floods in one decade were observed, separated by 1-3 decades with less frequent floods. When in the Mediterranean Europe floods dominate in the first half of the century, later from 1560 the flood belt extends across the whole western and central Europe. Among them there are local floods connected with heavy downpours, large rainy floods and snow-melt floods. Especially the first accords of the Little Ice Age seem to be simultaneous (1560-1570 AD).

The successive centuries of the Little Ice Age (till about 1850 AD) are well marked out in various flood records, which coincide with humid decades visible in advances of glaciers and in tree rings (Briffa, Schweingruber 1993). These last records show an interesting repetition of clusterings of heavy rains at the beginning of each century (ca 1590-1610, 1705-1715, 1800-1815). With that phase also correlate the high frequency of debris flows caused by heavy downpours in the Tatra Mts. (Kotarba 1995) and in Scandinavia (Jonasson 1991) as well as landslides connected with continuous rains and rainy seasons (Brunsden et al. 1997). At the transition to the warmer climate at the end of the 19th century the rise is recorded in the frequency of floods (Bielański 1984), which is also well marked at the western edges of Europe in

Britain (Rumsby, Macklin 1996) and Spain (Benito et al. 1996). The characteristic feature of heavy rainfalls in the 20th century are the clusterings (Starkel 1996, 1998) as well as the coincidence in several following years of continuous rains, heavy downpours and rainy seasons. The last clustering covers the years 1996-2000 and the previous one was observed in years 1958-60 (Zi̧tara 1968). Such clusterings cause passing of thresholds in the fluvial and slope systems and provoke the long-lasting transformation and even change in tendency of evolution (Starkel 1996, 1998).

6. Final Remarks

The presence of longer phases with various frequency of extreme events as well as of clusterings in several years needs explanation. The longer phases during the Holocene seem to coincide with the reduced solar activity and increased ^{14}C production (Magny 1993; Brown 1996; Chambers et al. 1999) as well as with superimposed frequent volcanic eruptions (Bryson, Bryson 1998; Starkel 1998). But the shift in time of wetter and drier decades and even longer time periods over the Europe may coincide also with dominance of either latitudinal or meridional circulation; the last one seems to effect frequent extremes (Rumsby, Macklin 1996). The end of this millennium delivers the example of such frequent disturbances connected with meridional circulation.

The message of last millennium left by alternating phases of higher and lower frequency of heavy rains and floods registered so distinctly in sediments, due to accelerated runoff and soil erosion in degraded geoecosystems, should be the lesson how we shall manage with the natural resources to protect them for next generations.

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