

# HISTORICAL FLOOD RISK MANAGEMENT: SPATIAL EXPANSION OF GHERGHIȚA VILLAGE (LOWER PRAHOVA RIVER)

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**ABSTRACT.** – **Historical flood risk management: spatial expansion of Gherghița village (Lower Prahova River).** This paper analyses settlements expansion in flood zones during historical time. We focused on the example of Gherghița village on Lower Prahova River by using a diachronic study in GIS. It revealed three major periods of extension of Gherghița village and flood risk management: (1) from Middle Age to the end of the 19<sup>th</sup> century – prevention against floods by expansion outside the flood-prone area; (2) during the major part of the 20<sup>th</sup> – flood negligence by expansion inside the flood-prone area; (3) at the end of the 20<sup>th</sup> century and at the beginning of the 21<sup>th</sup> century – protection against floods by extension inside the flood-prone area with structural measures (i.e. levees). As a consequence, human pressure on Lower Prahova River grew since the beginning of the 20<sup>th</sup> century, especially for agricultural purposes.

**Keywords:** diachronic approach (Middle Age – 21<sup>th</sup> century), flood-prone area, prevention / protection, human pressure, GIS.

## 1. INTRODUCTION

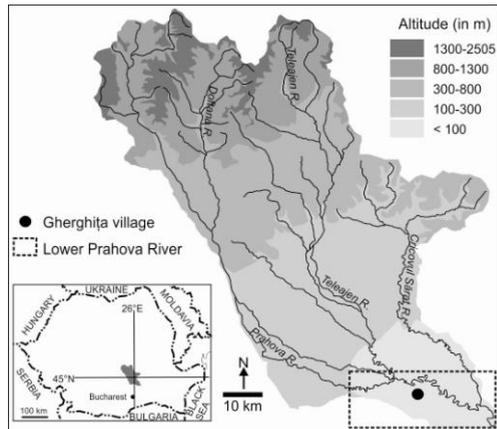
Settlement expansion in flood zones is an important component of flood risk management, because it is associated to various structural protective measures with impact on natural functioning of rivers (Früh-Müller et al., 2013). Geohistorical approach revealed various moments in the conquest of floodplains throughout Europe. For example, in Middle Age, major anthropic interventions have already taken place on some watercourses and their floodplains: on Danube in Hungary (Kiss, 2011); in Po Valley in Northern Italy (Curtis and Campopiano, 2014); in England and Wales (Lewis, 2010). In Main valley (Germany), expansion of settlements in flood zones, increasing demands for protection against floods and growing human pressures on rivers occurred after 1850 (Früh-Müller et al., 2013).

Regional studies showed that, generally, rivers from the south-eastern part of Europe still have intact landscapes (River Watch, 2012). In this context, the aim of our study is to determine when settlements extended in flood zones and, therefore, when human direct pressure started to trigger on these rivers.

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Our study focuses on the example of Gherghița village on Lower Prahova River (Fig. 1). It emerged as a market town in 14<sup>th</sup> century at a major crossroads and became a royal residence in 15<sup>th</sup>-16<sup>th</sup> centuries (Rădvan, 2010). Today, it has almost 2000 inhabitants (with the other villages forming a commune) and an agricultural economic profile (INS, 2013). The northern part of the village was affected by Prahova's overflowing in July 1975 and September 2005; in 2005, two houses were destroyed and 82 were affected in 70% (Ioana-Toroimac, 2009).



**Fig. 1. Study area – geographical position in Romania (frame down, left) and in Prahova River's catchment**

## 2. DATA AND METHODS

To determine the data of village expansion towards the flood zone, we employed a diachronic study. We used six documents from 1864-2011 time horizon: Southern Romania Map, Military Survey Map, two editions of topographic maps, orthophotos, and Google satellite images (Table 1). All the documents have initial different projections and they were converted in Stereo 70: Southern Romania Map by Bartos-Elekes et al. (2014), Military Survey Map by Crăciunescu et al. (2011), topographic maps within this study, orthophotos by National Agency for Cadaster and Land Registration; Google images were seen by using Pseudo Mercator within Quantum GIS. Only two elements have the same position on all the documents (i.e., two medieval churches); therefore, the comparison is difficult, especially between old and recent documents.

Within the diachronic study, we created eight layers. Churches were selected on all the documents. Buildings (including annexes and agricultural greenhouses), roads, river channel and scarps were digitized function of their representation on each document. Flood-prone area boundary, corresponding to 0.5 m water depth, was redrawn based on ANAR (2014). The position of archeological excavations comes from INP (2014). Levees were measured during field surveys of 2007.

The results of the diachronic study should be interpreted with certain precaution due to differences between documents: they have different initial projections, they have different scales, and elements are differently represented. For example, scarps are represented only on 1864 and 1899 maps; buildings are represented as quarters on 1954 and 1980 maps; building have a higher density on orthophotos and satellite images of 2005 and 2011 due to their detailed scale.

**Table 1. Documents used in this study**

Document	Year	Scale/resolution	Provenience (in this study)	Digitized elements
Southern Romania Map	1856 (Fligely survey)	1/57600	Bartos-Elekes et al. (2014)	Churches, buildings, river channel, scarps
Military Survey Maps	1896-1899	1/20000	Crăciunescu et al. (2011)	Churches, buildings, roads, river channel, scarps
Topographic maps	1954	1/25000	Army Topographic Service	Churches, buildings, roads, river channel
Topographic maps	1977	1/25000	Army Topographic Service	Churches, buildings, roads, river channel
Orthophotos	2003-2005	1/5000 (0.5 m)	National Agency for Cadaster and Land Registration	Churches, buildings (including annexes and greenhouses), roads, river channel
Satellite images	2011	2.5 m	Google Satellite	Churches, buildings (including annexes and greenhouses), roads, river channel

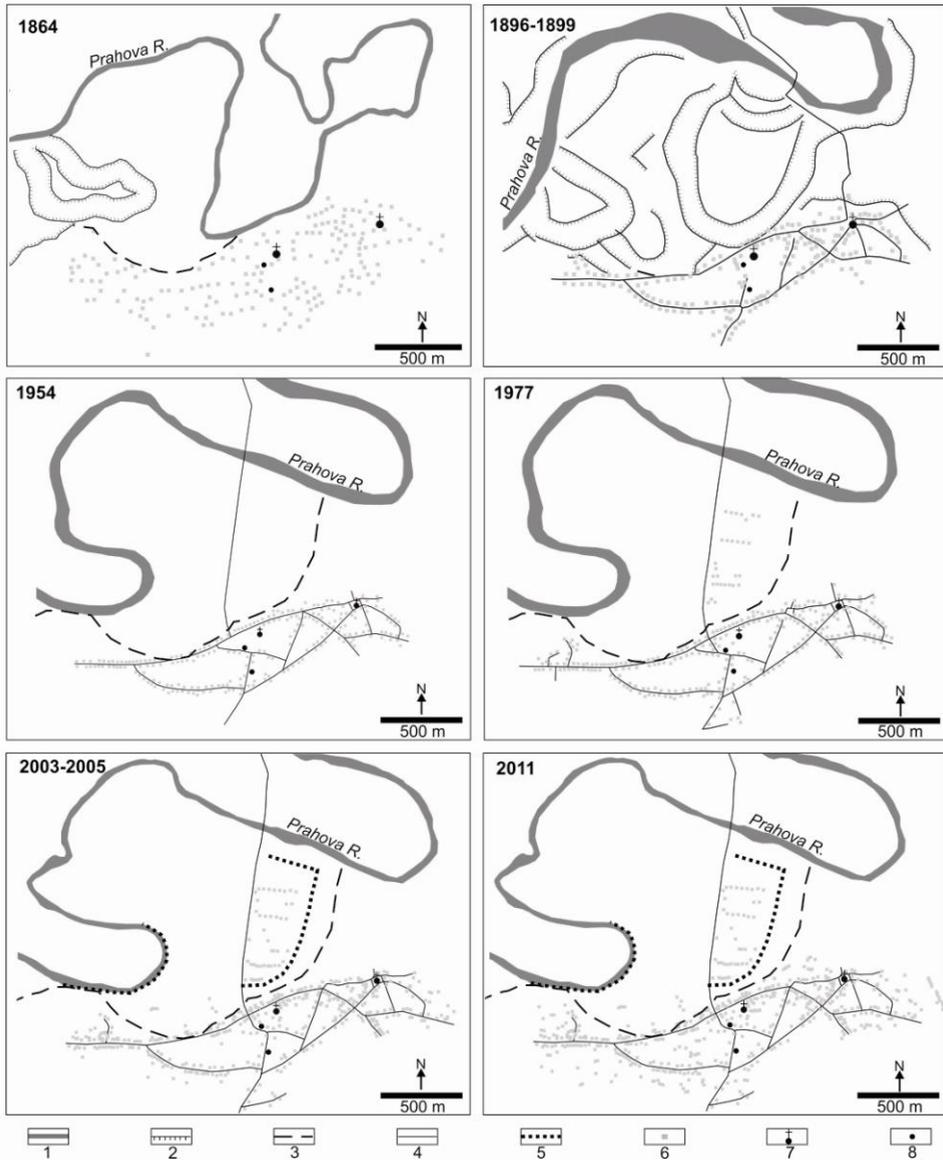
### 3. RESULTS

Lateral migration of Prahova River is indicated by meander scars (Fig. 2). Between 1864 and 1899, Prahova cut-off a meander in the southern part of the study area. Between 1899 and 1954, it invaded an older cut-off meander in the south-western part of the study area. Since 1954, lateral migration of meanders became less intense.

Flood-prone area boundary from the right side of Prahova River seems to correspond to abandoned channels of Prahova River. It includes the fluvial space used by the river for successive lateral migrations.

Buildings from Middle Age Gherghița were probably situated away from the flood-prone area as it is showed by the position of archeological excavations and two medieval churches (Fig. 2). This situation continued to the end of the 19<sup>th</sup> century. In the 20<sup>th</sup> century, buildings started to expand in the flood-prone area, previously uninhabited, in three phases: (a) between 1899 and 1954, in the north-western part of the village, along one of the main streets; (b) between 1954 and 1977, in the northern part of the village; (c) between 1977 and 2011, in the north-western part of the village. The location of new buildings from the first part of the 20<sup>th</sup> century maintained until the beginning of the 21<sup>st</sup> century. However, from the number of buildings digitized, those located in flood-prone area represented: 1.4% in 1954, 11.1% in 1977, 12% in 2005, and 9.5% in 2011.

Levees for protection against floods are situated along Prahova channel to protect the north-western part of the village and within a cut-off meander to protect the northern buildings. Both levees were constructed after 1977. They have approximately 2 km in length, equivalent to a quarter of the right side river reach.



**Fig. 2. Evolution of Gherghița village compared to flood-prone area. 1: river channel; 2: scarp (probably meander scar); 3: flood-prone area boundary (water depth = 0.5 m; redrawn from ANAR, 2014); 4: road; 5: levee; 6: building (or annexes, or greenhouses); 7: medieval church; 8: archeological excavations from Middle Age “La Târg” (north) and “Târgul medieval Gherghița” (south) (probably market town center, INP, 2014)**

#### 4. DISCUSSION

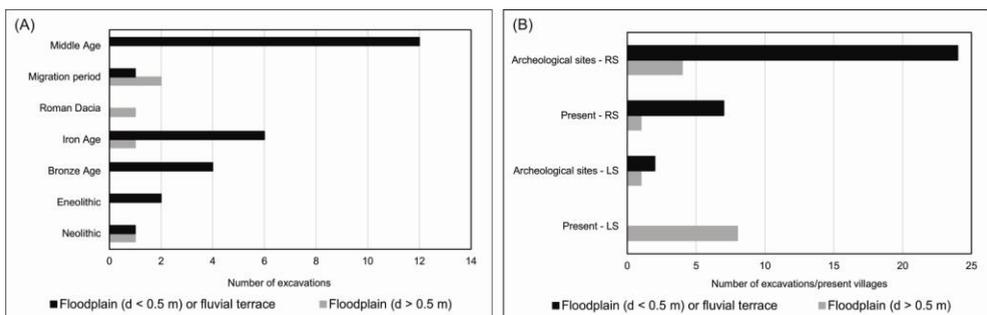
The diachronic study revealed three major periods of spatial expansion of Gherghița village: from Middle Age to the end of the 19<sup>th</sup> century – outside the flood-prone area; during the major part of the 20<sup>th</sup> – inside the flood-prone area; at the end of the 20<sup>th</sup> century and at the beginning of the 21<sup>th</sup> century – inside the flood-prone area with protection measures against floods (i.e., levees), impacting on river natural dynamics.

These periods may be associated to a changing strategy in flood risk management: (1) prevention, (2) negligence and (3) protection (Fig. 3). (1) Flood prevention period (from Middle Age to the end of the 19<sup>th</sup> century) was marked by settlement's development away from flood-prone areas. Excavations from northern archeological site of Gherghița revealed medieval houses buried at 0.8 m (Olteanu and Grigore, 2002), a level that generally corresponds to other European medieval excavations (Haslett, 2011), indicating probably the absence of floods. As a continuation in the 19<sup>th</sup> century, emerging legal norms encouraged people to build-up their houses on higher grounds (Bușă, 2006). In terms of spatial planning, this type of flood prevention may be interpreted as a proof of self-organization at the community level, according to needs and wise common will (Pușcașu, 2010; Gavrilă-Ardelean and Gavrilă-Ardelean, 2013); however, these decisions, issued from a local planning of autoregulation type, are not necessarily correlated on the Romanian territory (Pușcașu, 2009). (2) Flood negligence (1900-1977) was expressed by building-up within the flood-prone area. The conquest of the floodplains may be related to radical changes of land propriety and political wiliness. For example, the land reform of 1921 expropriated large landowners and distributed small plots of land to the rural population (Van Meurs, 1999); in Gherghița village, some building were constructed in an ancient fluvial channel. In opposition, the land reform of 1945, continued by similar decisions in 1959, characterized by collectivization and socialist restructuring of national agriculture towards development of planned agro-industrial centers and increasing agricultural productivity (Van Meurs, 1999); in Gherghița village, a zootechnical farm was built in the northern cut-off meander (Ioana-Toroimac, 2009). (3) Flood protection period (after 1977) resulted from levees' construction in the vicinity of abandoned channels and newly constructed buildings. Actually, several levees were built-up in Romania during this decade for protection against floods after their dramatic damages in 1970s (Turnock, 1979). In the shadow of these protections, Gherghița village extension in the flood-prone area continued for agricultural purposes (i.e., agricultural greenhouses); this may be related to the new land reform of 1991, reflected in land restitution and encouragement of smallholder farming (Van Meurs, 1999). However, after 2005 floods, the percentage of buildings located in flood-prone area diminished, indicating flood risk awareness and village expansion in the opposite direction, away from flood-prone area.

Years	1500	1600	1700	1800	1900	2000
Position flood-prone area	Outside				Inside, no protection	Inside, protection
Flood risk management	Prevention				Neglect	Protection
Possible causes					LR LR	F-L

**Fig. 3. Historical phases of flood risk management in Gherghița village. LR: land reform; F-L: levees for protection against floods**

The results for Gherghița village may be extrapolated for Lower Prahova River: local medieval population preferred to prevent the flood risk rather than protect from it like contemporary society. All archeological excavations from Middle Age are located in the exceptional floodplain (water depth < 0.5 m) or on fluvial terraces (Fig. 4A); actually, settlements from southern Romania Middle Age were near water sources, often aligned on terraces upon the everglades of rivers or next to lakes (Fieldler, 2008). At present, all villages located on right side of Lower Prahova River are outside flood-prone area, except for Gherghița (Fig. 4B).



**Fig. 4. Settlements' exposure to floods on Lower Prahova River. (A) Excavations within archeological sites located in the vicinity of Lower Prahova River (position and age of excavations according to INP, 2014; position compared to the flood-prone area according to ANAR, 2014; d: water depth). (B) Excavations and villages located in the vicinity of Lower Prahova River with built-up area exposed to floods (position compared to the flood-prone area according to ANAR, 2014; d: water depth; RS: right side; LS: left side)**

Compared to Main valley example (Früh-Müller et al., 2013), three particularities result for Gherghița village on Lower Prahova River. Firstly, in the case of Gherghița, the expansion towards flood-prone area occurred later, during the 20<sup>th</sup> century (compared to middle 19<sup>th</sup> century for Main example). Secondly, direct local human pressures started to impact on the river later, especially in the second half of the 20<sup>th</sup> century. Thirdly, in the case of Gherghița, the expansion is related to agricultural economic profile of the region (compared to industrial one for Main example).

## 5. CONCLUSION

In Gherghița village, settlements expansion in flood-prone area started in the first part of the 20<sup>th</sup> century and has been increasing since. The main local measure with impact on river channel is levees' construction for protection against floods, at the end of the 20<sup>th</sup> century.

However, in Gherghița, only a small part of the village (a maximum of 12% of buildings in 2005) is located in flood zone and flood protection measures act on a local spatial-scale. This advantage, consisting in a traditionally prevention strategy face to flood risk, should be preserved. Therefore, flood risk management and spatial extension of settlements in flood zones should be better related through spatial planning.

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