Riverscape changes in the Lower Siret Basin in the late Little Ice Age

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ABSTRACT: Research focusing on the environmental history of the Lower Danube region is rather scarce compared to the progresses made for the upper and middle sections. Moreover, little is known about the effects of recent climatic fluctuations and increasing anthropogenic pressure on the highly sensitive river systems of the area. In this paper, the information available in various historical sources (charters, narratives and historic maps) was used to carry out cartographic reconstructions of the riverscape in the former borderland of the Romanian Provinces from the fifteenth century to modern times. The results indicate that significant hydrographical disturbances occurred throughout this period and the present day configuration of the drainage network is relatively recent. The diversion of the lower course of river Siret at the beginning of the seventeenth century led to several other hydrological and hydrographical alterations, such as channel planform changes, supplementary channel shifts of the tributaries or increased incision into the floodplain. The origin of the triggering factors is to be found in the interplay between natural conditions and human activities.

KEY WORDS: rivers, charters, cartographic reconstruction, environment change.

1. Introduction

In various regions of Europe several periods of increased fluvial activity or accelerated runoff have been identified during the Holocene (Perșoiu and Radoane, 2017; Notebaert and Verstraeten, 2010; Starkel, 2002). These were related to the effects of climate deterioration, socio-economic changes or a mixture of both. Significant for modern times in terms of magnitude and frequency of extreme hydro-meteorological events is the 'Little Ice Age' (LIA) – a period that roughly started in the Northern Hemisphere between 1200 and 1400 and ended in the 19th century (Wanner et al., 2022). During LIA, the available scientific, archaeological and historical data indicate a variable climate in the Carpathian region, with frequent and significant episodes of heavy rainfall, overall long winters and cooler summers. The slight overall increase in precipitations caused significant changes in the water balance. Lake water levels peaked in the sixteenth and seventeenth centuries, groundwater levels progressively increased until 1600 and major floods occurred frequently (Kiss and Laszlovszky, 2013; Kiss, 2019). Snowmelt and ice movements on the rivers often resulted in ice-jam floods at the end of severe winters, while the largest and most

destructive floods usually occurred during the summer months subsequent to successive days of heavy rainfall (Vadas and Rácz, 2013). Nevertheless, the wet spells and flood peaks interspersed with extreme droughts and depletion of large rivers or the complete drying of smaller ones (Bartholy et al., 2004; Glaser et al., 2010).

The adverse impacts of LIA hydro-climatic conditions on the river mobility have been historically documented for several rivers in Central-Eastern Europe. Noteworthy changes of the main courses occurred along the Slovak section of Danube (between 1378 and 1526), in Hungary - where river Rába abandoned its channel and moved to the former bed of Stremen (prior to 1406), and Poland, where Vistula successively changed its course in the fourteenth, fifteenth centuries and 1593–1595 (Pišút, 2006; Kiss, 2019; Maruszczak, 1997). In the Lower Danube region, a major shift of the lower course of Siret River in the sixteenth century was briefly discussed for the first time in 1929 by Antonovici and reiterated by various historians afterwards (Constantinescu-Mirceşti and Dragomirescu, 1964; Gonţa, 1971). However, an analysis of the changes was hardly documented and the subject remains largely unknown to environmental scientists.

Based on the available historical and geomorphological data, this research aims to present a cartographic review of the main fluvial adjustments occurring in the north-eastern part of the Lower Danube Plain during LIA and to bring forth new understanding on the environmental changes of the past five centuries.

2. Study area

The north-eastern part of the Lower Danube Plain (Romanian Plain) is a remarkable 10 to 30 kilometres broad floodplain drained by the Siret River (the third largest tributary of the Danube) and a major convergence zone for the rivers draining the adjoining physiographic units. Geologically, the floodplain is located in a broad tectonic basin which accumulated thousands of meters of sediments from the upland catchments. Despite the smooth and featureless aspect, the plain includes a range of distinctive physical landscape units. To the west, where Carpathian and Subcarpathian tributaries gradually deposited their coarse grained sediments in alluvial fans since the Lower Holocene, elevations are higher and the slopes slightly steeper. The long-term fluvial aggradation and the development of alluvial fans were conceivably associated with drainage instability and led to a progressive eastward deflection of main river course. In more recent times, the unsteadiness of river channels in the area is confirmed by the presence of distinctive features such as channel cut-offs, oxbows, meander scars, abandoned side channels and relict meander belts (Fig. 1, c).

The region was prone to frequent flooding in the past and persistent wetlands covered much of the territory until the mid-twentieth century. On certain occasions, extreme hydroclimatic events easily amplified the lateral migration of channels or the rapid abandonment of channel belts in favour of new courses (avulsions), thus causing temporary or permanent disruptions in the river pattern. Whereas few such events were explicitly recorded, they may occasionally be inferred based on toponymical research and historical data. Consequently, the Romanian geographer Simion Mehedinţi vividly noted in 1931:

‘Here the streams didn’t have stable beds. For example, the Bârlad instead of flowing into the Siret next to Hanu Conachi as nowadays, emptied previously directly into the Danube and the Siret flowed in a southerly direction, wandering and looping into a vast floodplain. Only recently, the Siret shifted to the north, invading and swallowing the channel of Bârlad, like a big fish swallows a smaller one. And there were other changes…’.

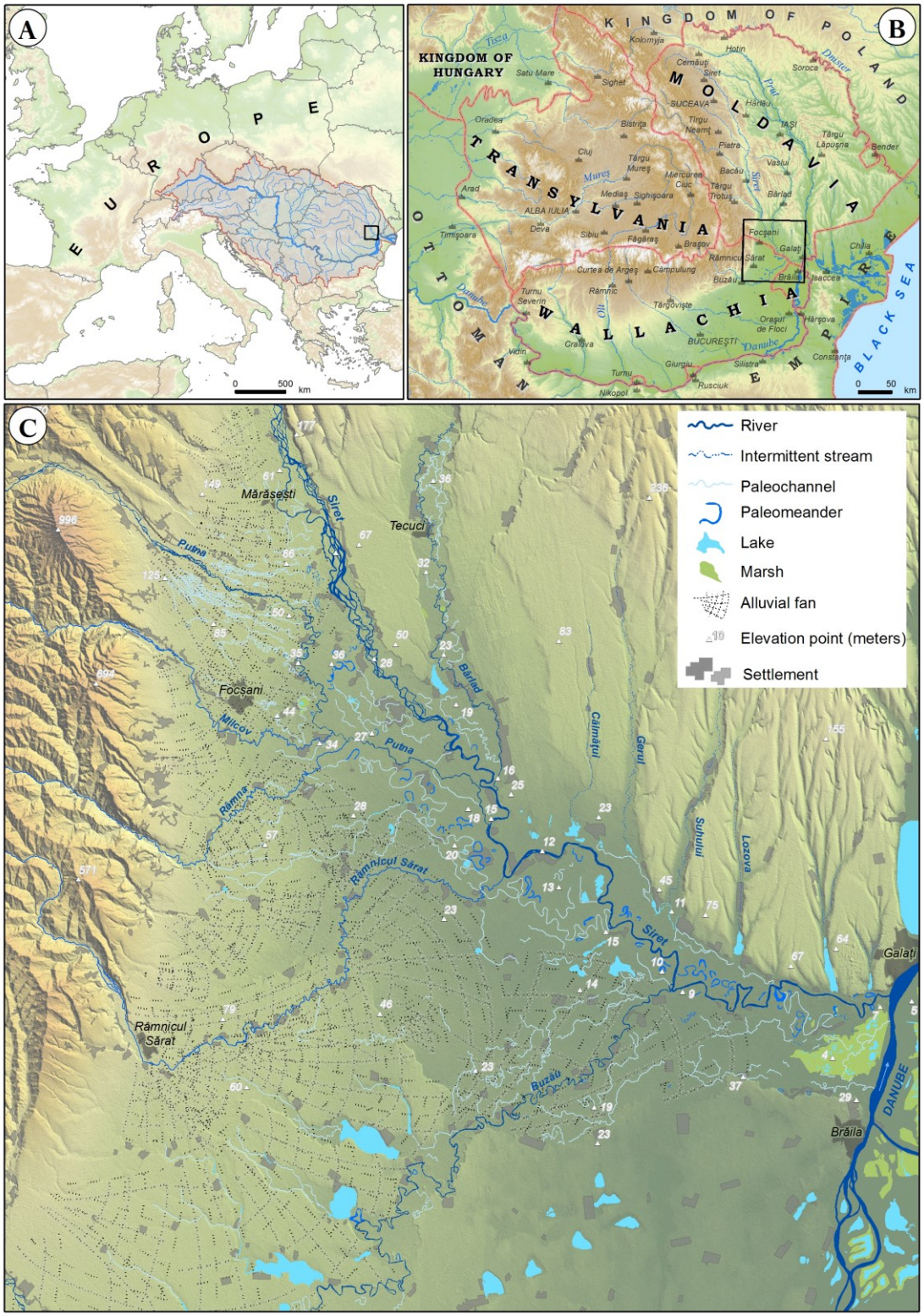


Figure 1 Geographical and historical setting of the studied area. Map (a) shows the location within the Danube River Basin; (b) indicates the political-administrative situation of the territory in the sixteenth century; (c) shows the drainage network configuration at the beginning of the nineteenth century.

The geomorphic and hydrological features of Siret floodplain typically acted as restrictive geographical controls for the development and persistence of settlements. The map of early medieval sites shows very few findings in this region compared to the higher adjoining areas, where numerous settlements have been documented since the Neolithic. The situation apparently changed starting with the late fourteenth century as a result of the political and demographic expansion of the emerging states of Moldavia and Wallachia towards the mouth of the Danube. In the fifteenth century the floodplain was divided in terms of administration between the two states and the frontier was traditionally established along the Milcov and Siret rivers (Figure 1, b). Although the number of dwellings increased and economic activities flourished during the next centuries, natural disasters and recurring military conflicts continued to have great impact on the stability of most settlements and only a small number survived until modern times. The emergence and gradual development of these 'scattered' villages were nonetheless related to the presence of aquatic resources – river corridors, lakes and ponds. The most important commercial routes of that time followed the major waterways to Danube's ports – Galaţi in Moldavia or Brăila in Wallachia, and countless settlements emerged along rivers, at various crossing points or at river confluences. Additionally, hydraulic power, fishing ponds and the persistence of tight grows of woody and herbaceous plants in the floodplain provided significant economic resources and increased land value.

3. Historical approach

Historical information related to the rivers draining the former border region between Moldavia and Wallachia is remarkably scarce, with only a few encyclopaedic works written in the seventeenth and eighteenth centuries containing valuable descriptive details regarding the Moldavian hydrography. Moreover, historic maps produced before the late seventeenth century can hardly be analysed due to their lack of details, reduced accuracy and obscure survey dates. In this case, an alternative for the study of hydrographical changes in the past centuries may consist in the available collections of charters (*Documente privind istoria României, Documenta Romaniae Historica* - DRH*, Catalogul documentelor moldoveneşti din Arhiva istorică centrală a statului*) and more sparse observations logged in chronicles (e.g. *Cronicile României*, hereafter CR) and travel accounts (e.g. *Călători străini despre Ţările Române*, hereafter CSTR). The charters, translated from Slavonic by a large number of historians, are related to the transfer of property rights and usually confirm land ownership, in general, or within certain boundaries. With few exceptions, these are the only written documents preserved from medieval times, mostly in ecclesiastic archives. The number of preserved land titles constantly increased in Moldavia and Wallachia starting from the second half of the fourteenth century, coeval with the development of state chancelleries, but it should be noted that their number roughly reflects the actual number of documents once issued. Because of their pragmatic approach, the charters are not easy to read or interpret but often record geographical details and are exactly dated.

In order to investigate the regional hydrography for different time periods and detect fluvial changes occurring from the fifteenth to the eighteenth century, more than 300 documents referring to settlements, lakes or river confluences in the proximity of Siret and its main tributaries were considered in this research (Fig. 2). A key feature of the approach was the assessment, with a reasonable degree of accuracy, of a settlement location at a certain time or in different time periods, based on historical records, historic maps, adjacent geographical features, place names or administrative borders.

With few exceptions, most of the settlements taken into account were relatively small and extremely sensitive to the natural, socioeconomic or conflict relapses. In the considered time period, some settlements decayed and were deserted, some persisted on the same location, occasionally with different names, whereas other changed their location in the surrounding administrative area. For instance, the settlements located until the nineteenth century between the present day courses of Siret and Bârlad preferred the forested marshy area of the floodplain, most likely because it offered better protection in a time of frequent military conflicts. However, these villages were subsequently relocated to the higher ground of Bârlad terraces (on the left side), as a consequence of the major floods which occurred in the nineteenth century.

Figure 2 Examples of historical sources used in this study: (a) charter from 1644 concerning the sale of several estates in Moldavia, located between the rivers Siret and Lesser Siret (Source: National Library of Romania); (b) fragment from the map entitled Indice topografico del principato di Valachia (1718) showing the Siret and Lesser Siret confluence (Source: National Library of France).

The spatial context of historical information was summarized using a geographical informational system (GIS) and compared with the paleodrainage imprints revealed by high resolution imagery or detailed maps. Based on the results yielded by this approach, several reconstructions are proposed.

3.1. River routes in the fifteenth and the sixteenth centuries

According to the main collections of Moldavian charters, only few texts were issued or survived prior to the mid-fifteenth century (nine for the fourteenth century and 287 dated between 1400 and 1450), as compared to more than 500 documents emitted by the end of the century. Only a small number of these refer to settlements situated in the proximity of the lower courses of Siret

or its tributaries, indicating a rather sparsely populated area. Nonetheless, the information contained is surprising considering the present day location of the river courses.

For instance, a charter from 1423 indicates the presence of three small villages on the lower course of Putna River which would be located today at about two kilometres north from the current riverbed along an abandoned dry channel (namely Putna Seacă or Dry Putna). Other charters refer to villages or lakes situated along Bârlad River, such as Fundeni (in 1495 – 'on the Bârlad'), Tomceşti (in 1495 – 'village on the Bârlad, namely Tomceşti, the upper part, and half of the fishing breakwater on the Bârlad river'), Ciofreştii (in 1496 – 'village on the Bârlad, on the shore of the great lake of the Bârlad river, on the river mouth of Geru'), Piscul (in 1495 – 'village named Piscul on the Bârlad...and half of mill on the Bârlad'), Ţăpeşti (in 1499 – 'on the Bârlad river, with the Lozova lake'), which can be currently pinpointed along Siret River.

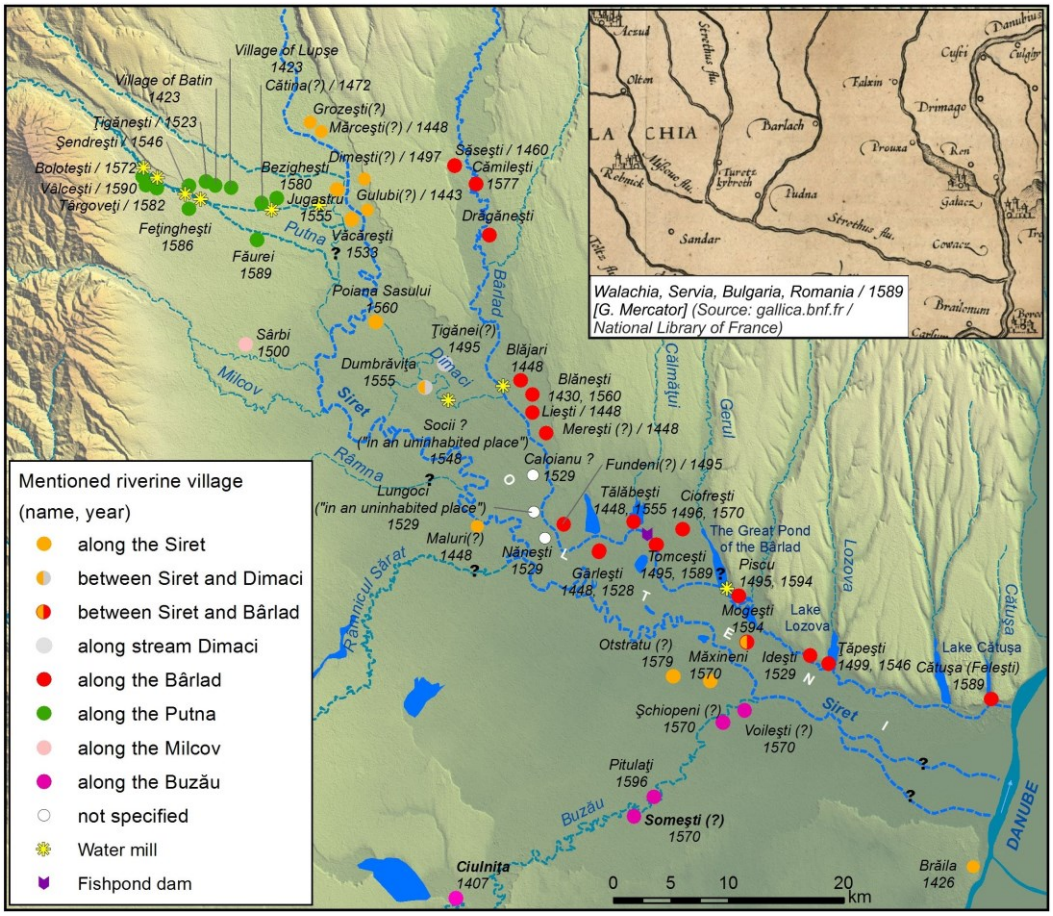


Figure 3 A hypothetical reconstruction of the river network at the end of the sixteenth century based on charter data, and the situation depicted in a map from 1589 (in the inset).

Despite its paucity, the available information strongly suggests that at the end of the fifteenth century Bârlad River had a longer lower course towards the Danube, whereas Siret was located westward compared to its present course (up to 10 km). By relating this data to the earliest cartographic descriptions of Eastern Europe, which was highly influenced by the 'rediscovery' of Ptolemy's Geographia, the picture becomes far more comprehensive. The major known fifteenth

century maps provide little detail and lack the names of the tributaries of main rivers in the region, while most of the depicted settlements are misplaced.

The establishment of a stable Moldavian-Wallachian frontier (1482) on the rivers Milcov and Siret (hardly depicted on the maps until the seventeenth century) additionally confirms that, at the end of the century, Siret was a direct collector of all the main Carpathian and Subcarpathian rivers – Putna, Milcov and Râmna (nowadays tributaries of Putna), Râmnicul Sărat and Buzău.

From the sixteenth century onwards the number of charters and mentioned settlements increased and some of these continued to indicate the persistence of a longer course of river Bârlad. For instance, charters from 1514 and 1520 again place along the latter river most of the aforementioned villages and water bodies, such as the confluence with Gerul River and the Lozova Lake, but many other riverine communities are revealed for the first time . The southernmost one – Cătușa, adjoining the homonymous river and lake, incidentally confirms that by the end of the century river Bârlad continued to flow towards Danube (Fig. 3).

Interestingly, in the internal documents dating back to the fifteenth and sixteenth centuries, the Moldavian part of the floodplain encompassed between the two river courses is referred to as 'Olteni', therefore many historians associated it with a presumed earlier colonization with people from the lower course of the Olt River, in Wallachia. However, recent studies tend to consider this scenario a classic case of circular historiographical reconstruction, exclusively based on a hypothesis assembly (Coman, 2013). Without excluding other possible justifications, the name should also be considered from a linguistic perspective. According to Duridanov (1969), the Indo-European root *olta, *oltos, which is at the origin of the more common form *alta in Thraco-Dacian, Italic or Balto-Slavic languages, is generally related to water and rivers. Similarly with the ancient name of the Olt (Alutus), Altina (Oltina, near Lower Danube), the Venetian Altinum, or Altina in Lower Pannonia, the expression is likely to be used for a frequently flooded region, with swamps and water excess.

Regardless of the significant progress made by cartographical representations in this century, reflected in their sheer number, details or mapping scale, none of the available historic maps of the study area can be considered reliable for an accurate reconstruction of the river network. The various published maps depict river Bârlad as a tributary of Siret (see the inset map in Fig. 3), in sharp contrast with the information contained in coeval charters.

3.2. The seventeenth century: 'a big fish swallows a smaller one'

During the sixteenth and seventeenth centuries the fight against the influence of the Ottoman Empire in the Romanian Principalities reached new heights, causing much devastation in the region. In Wallachia the territory broadly enclosed by the lower courses of Buzău, Siret and Danube, including the fluvial port of Brăila, was under military occupation from 1539 to 1542 and remained under direct Ottoman administration for nearly three centuries. Consequently, little information regarding the villages and riverscape of the region is known. However, the same period overlaps the early stages of Romanian written culture in the form of annals, chronicles, poems or historical studies, some of which comprise accurate geographical details.

The most expressive works of that period pertain to the Moldavian nobleman Miron Costin (1633–1691). In the first one, a register relating Moldavian events from 1594 to 1662, Costin provided some geographically relevant details, such as the Milcov river branching in the lower course – the smaller northern distributary formed the official border between the Principalities, while the southern branch ('the Greater Milcov') streamed further into Wallachia. His second work (from about 1677), however, contains remarkable descriptions of the main Moldavian streams. Referring

to river Siret, the author noted that 'it exits from the mountain range that separates us from Transylvania...and flows into the Danube, between Brăila, a Turkish town, and our Galaţi, taking along the waters of many rivers, ours or Wallachian. Moreover, this river separates us from Walachia, downstream of Focşani'. Its tributaries were not forgotten, either. In Moldavia, 'Putna similarly springs from the mountains and flows into Siret north of Focşani...', 'the Milcov...is an even smaller river that flows from the Hungarian mountains to Siret, separating us from Walachia…' and 'the Bârlad, a rich river flowing from the woods of Roman through beautiful and fertile places, joins the Siret and afterwards (curiously) splits up carrying the same volume of water, emptying all by itself into the Danube'. The latter is additionally mentioned when Costin describes the Roman fortifications in Moldavia – 'the ruins near Galaţi, on the Bârlad, were erected either by the Romans or Dacians' or 'in the ruins close to Galaţi…where the Bârlad River falls into Danube, a yellow copper coin was found'. Referring to Walachia, the author noted that "the Great Milcov, Râmna, Râmnic and Buzău are all rivers springing from the Hungarian mountains that flow into our Siret" (Costin, 1958).

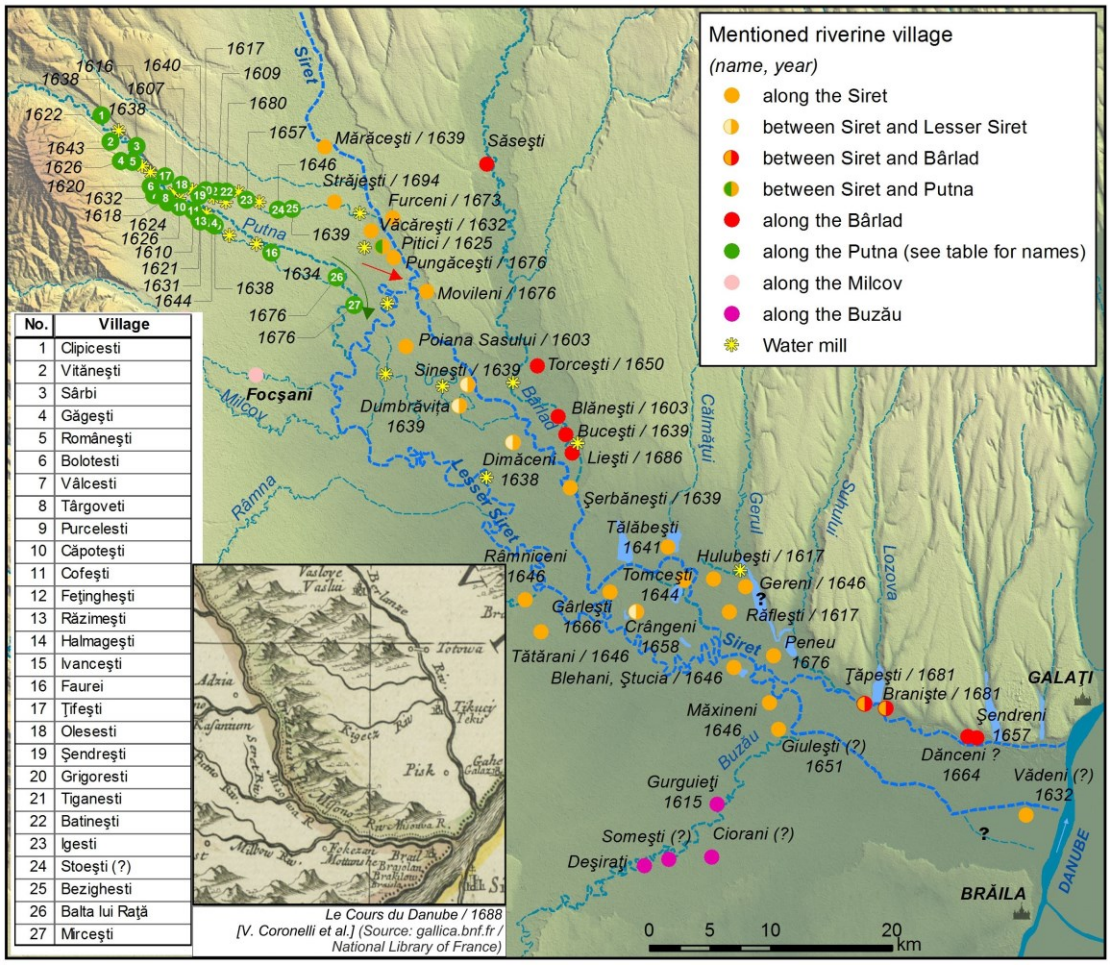
These reliable geographical observations made by the Moldavian chronicler depict a major hydrographical change which occurred, most plausibly, in the first half of the seventeenth century: The course of river Siret diverged eastward, partially along the previous route of Bârlad. The former lower courses (still preserved at that time) continued to be named differently, confusing the writer.

The chancery documents greatly reflect these changes. A charter issued in 1638 which fully depicts the administrative limits of the village Dimăceni, states that the territory was bounded to the west by the 'Lesser Siret' (Sireţel) and further eastward the limits crossed over the "Greater Siret" to the Bârlad. The information acknowledges a prior diversion of the main river, from the older course to the east, and the anastomosing pattern of river channels. The western anabranch – the Lesser or the Older Siret, continued to collect most of the Carpathian and Subcarpathian tributaries and remained, after the confluence with Milcov, the traditional frontier between Moldavia and Wallachia (as shown in 1643). The eastern anabranch ('the Greater Siret' or, simply, the Siret) overlapped the previous course of river Bârlad south of Şerbăneşti (located in the river proximity in 1639). Consequently, the downstream riverine villages and former tributaries started to be placed along Siret and the settlements in the enclosed flood basin remained '*between the Sirets*' (see Fig. 4). An early traveller in the region, the secretary of the Polish diplomat I. Gninski, recorded in his travel journal (1677) that the road 'from Tecuci to Galaţi follows the valley of the same river (Bârlad) and, after its confluence with Siret, it follows the latter one' (CSTR 5, 356), yet for the local people, such as Costin, the same road to the Moldavian port conventionally continued to be named 'the Bârlad route' (CR 1, 294).

Close to the bifurcation point of Siret, Putna consistently used the same path in the lower course during the early seventeenth century. Due to an increasing economic interest for milling, millraces were developed along the former distributaries, such as 'the Upper brook' and 'the Lower brook' (occasionally 'the Greater brook'), serving several villages, many of which are now extinct. Among these, only one is explicitly mentioned as simultaneously located in the proximity of Siret (1632), suggesting that both of the distributaries emptied narrowly in the same area. The situation apparently changed by the end of the century, when it was stated that 'the Lesser Siret is now joined with Putna' (1688), which presumes a southward deflection of the watercourse towards the ancient branch of the Siret (Constantinescu-Mirceşti and Dragomirescu, 1964).

Unfortunately, none of the known charters can be used to infer the spatial arrangement of the various river branches and floodplain water bodies in the vicinity of the Danube, such that most of the details originate in the observations of foreign travellers. In 1632, the Maltese monk Paolo

Bonnici found the Siret–Danube confluence close to the Ottoman village Vădeni (CSTR 5, 20), while the more famous Katip Çelebi noticed (around 1650) the presence at the Lower Danube of 'a part of Siret' near Brăila and of the river Bârlad near Galaţi (Guboglu, 1974). By relating this information with the description given by Costin for the lower course of Siret, it appears that Bonnicio referred solely to the main mouth of the river, whereas in the account of Celebi - Bârlad was only the lowermost reach of the former watercourse, at that time a distributary channel of the Siret to Danube. This secondary channel was at least twenty-five kilometres long, based on the account of another missionary, Antonio Giorgini, who found it in 1688 close to the village Piscu: 'on one side of the settlement flows the Bârlad, very dangerous for the travellers since it has no bridges and flows very fast' (CSTR supl.1, 223).



No.	Village
1	Clipicesti
2	Vităneşti
3	Sârbi
4	Găgeşti
5	Românești
6	Bolotesti
7	Vâlcesti
8	Târgoveti
9	Purcelesti
10	Căpoteşti
11	Cofeşti
12	Feţinghești
13	Răzimeşti
14	Halmageşti
15	Ivanceşti
16	Faurei
17	Ţifeşti
18	Olesesti
19	Şendreşti
20	Grigoresti
21	Tiganesti
22	Batineşti
23	Igesti
24	Stoeşti (?)
25	Bezighesti
26	Balta lui Raţă
27	Mirceşti

Figure 4 A hypothetical reconstruction of the river network at the end of seventeenth century based on charter and narrative data, and the situation depicted in a map from 1688 (in the inset). Channel changes are indicated by arrows.

An overall perspective on riverscape complexity in the floodplain area at the beginning of the eighteenth century is given in the journal of a Polish diplomatic mission (1700): 'in Piscu we crossed again the already mentioned Bârlad river. This river empties into the Siret at Şerbăneşti. From here, flowing down on the plain for some time, the river splits into branches. Across the

Siret, further west, the Milcov River comes from the mountains of Odobeşti and afterwards diverges to Focşani… separating Moldavia from Wallachia, and then, proceeding deeper into Wallachia separates the countries down to the Danube. From the top of the hills near Galaţi, one can have a broad viewshed on the valley and distinguish the Bârlad, Siret and Milcov (note - the Lesser Siret) rivers, which empty into the Danube through different mouths' (CSTR 8, 170).

While most of the cartographical products of that time are barely amended copies of the earlier ones and can hardly be used to infer the mentioned hydrographical changes, some contain intriguing details. One of these maps, which supplemented the narrative of Çelebi, shows that the last tributaries of the Danube, from the east to the west, are Prut, Bârlad and Siret. This lesser known mid-seventeenth century map (1648) is the oldest cartographical source depicting river Bârlad ('*nehr-i Purlat*') as a tributary of the Danube (Radu-Popescu, 1985). A more notorious map compiled by V. Coronelli et al. (1688), illustrates river Bârlad in a similar manner, flowing concurrently with the Siret (confusingly named Milcov in the lower course) towards the Danube. Moreover, this map indicates the presence to the west of a disrupted river channel (confusingly named Siret; see the inset map in Fig. 4). By relating this data with the historical information provided by documentary and narrative sources it becomes apparent that the authors had some reliable geographical data at their disposal for the Lower Danube region, although their work is still largely the outcome of a subjective perception on the geographical reality, common to the 'cabinet geographers'.

More accurate insights were provided only a decade later, following the Habsburg expansion in the former Ottoman territories and the increased interest for map-making in the Romanian provinces, generally supported by Greek scholars and cosmographers. For example, a map draft used by Luigi Marsigli for delineation of the frontier at the end of the Great Turkish War of 1683–1697 illustrates the Siret flowing into the Danube through a couple of channels, similar to the description provided by Costin (*Prima pars mappae integri tractus confinium cujus divisio correspondet cum novissima scriptura, sub dato 14. augusti quae continet confinium mediatum cum Turcis, per Valachiam et Moldaviam in Transilvania ad usum tractationis pacis*). Furthermore, the first Wallachian map drawn at the request of the high steward Constantin Cantacuzino (1700) pinpoints the location of the Lesser and Greater Siret confluence and the river mouth near Brăila. Additionally, the latter source indicates that by the end of the seventeenth century the ancient channel of Siret was no longer an active branch but a nearly parallel tributary, supplied by most of the Carpathian and Subcarpathian side streams (see Fig. 2, b). Based on these examples, it may be concluded that at least some of the maps drawn during this century contain details which are comparable chronologically with those extracted from internal documents and narrative sources. To date, this correspondence has not been observed for the sources of the previous centuries.

3.3. The eighteenth and early nineteenth centuries: 'a blurred gully' and a volatile frontier

Geographical knowledge in the Romanian Principalities was consistently enriched during the eighteenth century, particularly following the elaboration of the works of Prince Dimitrie Cantemir – a colourful description of Moldavia and the first detailed map of its territory (most likely in 1714–1716). In 'Descriptio Moldaviae' an entire chapter is dedicated to the hydrographical description of the Principality. Here the author noted that 'the Siret…empties into the Danube using two river mouths', 'the Bârlad...joins the Siret in the vicinity of the village Şerbăneşti' and among other tributaries are the Milcov and Putna rivers, 'namely the Lesser Siret, after these streams are joining'.

The observations made by Cantemir support the idea that Siret continued to have a divergent flow towards the Danube in the first decades of the eighteenth century. However, the river distributary near Galaţi is no longer named Bârlad as it had been previously designated (‘not far from here, at the eastern mouths of the Siret, the ruins of an ancient fortress…are still visible’), reflecting a better understanding of the riverscape changes of the seventeenth century. This is further pointed out by other historical sources, such as the diplomatic journal of Filip Orlik, hetman of Ukraine (1722): ‘this earthen wall, made by Trajan (near Galaţi), is the place where Siret empties into the Danube’ (Panaitescu, 1930). However, it is noticeable that the Moldavian prince had no information concerning the origin of the Lesser Siret, nor of the former channel of Putna. According to his map, the latter watercourse was already deflected southward and, following the disconnection of the Lesser Siret, inherited downstream much of its historical route and tributaries. Consequently, the military engineer I.C. Weiss disconcertedly mentioned in a report from 1737 that the watercourse is named Putna upstream, Milcov subsequently, and lastly Lesser Siret (CSTR 9, 190).

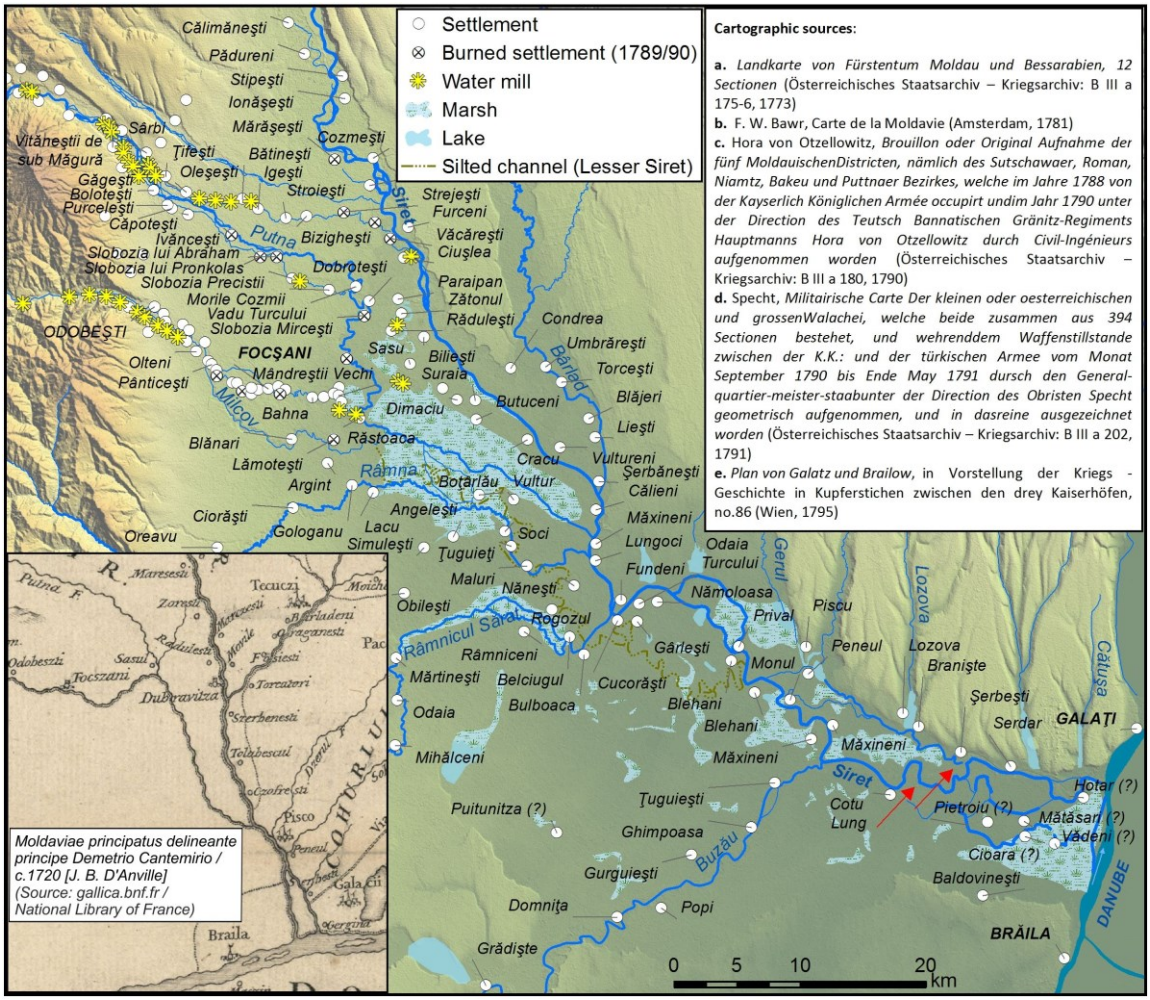


Figure 5 Hydrographical reconstruction based on several historic cartographical sources from the late eighteenth century. The inset map shows the situation described in Cantemir’s times. Red arrows indicate the shift of Siret channel in the ‘Ruptura’ area.

Regardless of the name used to describe it in various sources, the older channel of river Siret remained active for a short period of time and was gradually silted between 1737 and 1769-1772, as shown by the expeditious survey of General F.W. Bawr during the Russo-Austro-Turkish war. The same map indicates also that the southern connection of the Siret with the Danube was no longer efficient (Fig. 5).

Disruption of the Lesser Siret subsequently affected the stability of the lower reaches of former Carpathian and Subcarpathian tributaries. For instance, river Putna, downstream of the confluence with Milcov, diverged eastward to the Siret maincourse; Râmna diverged to Putna, and Râmnic extended its lower course to Siret, most likely along the former channel of the extinct river branch. These details are overally confirmed by the Habsburg cartographical surveys of the Danubian provinces in 1788–1791. In the description of Wallachia made by Specht, extended marshes contouring the former channel of the older Siret are visible in the region and some of the represented rivers split off into multiple threads. The picture is specific to a low gradient landscape where rivers frequently overflow and the drainage has an unsteady and indefinite pattern, as was the case of river Râmna which continued to flow into Putna, but was a tributary of Siret as well.

Various documents of that time accounted the Lesser Siret even after its disappearance, and the Moldavian-Wallachian frontier remained established until 1862 (the date of the political union of the Principalities) on the meandering path of the former riverbed. It appears the river was still a frontier watercourse in 1734–1755, but was referred to in various later documents as an 'the old channel of River Siret' (1824), 'a frontier' (1826), 'an ambiguous borderline' in 1835 ('since it was mudded by the Râmna River'), 'a ravine' (1864) or 'a blurred gully' in 1884 (Constantinescu-Mirceşti and Dragomirescu, 1964). Subsequent to the progressive silting of the Lesser Siret channel, the lower courses of the former tributaries underwent other minor changes in the first decades of the nineteenth centuries, and the actual configuration of the regional river network dates mostly from that period.

The long term stability of the ancient Siret borderline regardless of the various hydromorphological alterations is less accounted for the lowermost reach, which separated Moldavia and the Ottoman district of Brăila. In the beginning of the eighteenth century, the frontier was located along the southern distributary of the Siret (see the inset map in Fig. 5), but subsequently changed to the northern one (1819), probably due to another avulsion and river branch disruption. Although there is no clear information about the time of the watercourse shift, the former branch can be easily recognized in the later cartographic sources from the 1769–1774 and 1789–1791 wars. Several details are also provided with the occasion of the lawsuits filed by the Moldavian customary land owners for their respective land loss. A document from 1823 refers to some affected land estates which extended 'over the Bârlad' to the former course of Siret, mentioning that 'after the avulsion of Siret, the watercourse moved in the channel bed of Bârlad and established there. The beyond-river lands remained ours until 1819. From this on, the mayor (subáșa) of Vădeni occupied it and did not allow us to use our habitual rights' (I. Neculce. Buletinul, 1930). A witness testimony in 1836 additionally indicated that the disputed land was situated between the antique earth wall ('troian') near Şerbeşti and Cătuşa valley, therefore the avulsion point should be located in the Ruptura (the Breach) area from the Austrian mid-nineteenth century map (see also Fig. 5). After the restitution of the former Ottoman lands and restoration of the Wallachian authority in Brăila, the frontier delineation works of 1831 basically confirmed the status-quo and, downstream of the 'breach zone' the borderline remained established on the 'flowing Siret' instead of the customary channel. Consequently, the Moldavian territory lost about forty square kilometres!

4. Environmental approach

Although the various historical data used in this study indirectly provide valuable clues for the assessment of permanent hydrographical changes at regional scale, the attempt to establish causal relationships and disentangle the role of climate and human impact is not a straightforward task. In this section we aim to correlate our observations with previous environmental research and to highlight the main factors that could explain historical changes of hydromorphological nature, such as channel avulsion or alluviation. We consider direct factors with a rapid effect - such as climate variability or human interventions on rivers, but also indirect factors - such as land use/land cover changes.

In the lower basin of the Danube, fragmentary and subjective information recorded in chronicles and journals of the foreign travellers confirms for this period the occurrence of a large number of hydroclimatological events (heavy rainfall, storms and floods) in the warm season, in addition to the severity of the winters. Considering the historical weather database compiled by Topor (1963), the reconstructed shift of the lower course of river Siret in the beginning of the seventeenth century followed a period of heavy rainfall and severe floods that may have triggered the avulsion. For instance, prolonged rainfall was recorded in 1615 which lasted from 22th May to 26th July, whereas continuous major floods affected Transylvania and the adjoining provinces in June–July 1618.

From a broader perspective, the hydromorphological changes occurred during an episode of climate deterioration which has been accounted across Europe in various sources, and the fluvial response to climate variability was probably widespread. An increase in flood event frequency and intensity at the end of the sixteenth and the early seventeenth century is well documented for several rivers in Central–Eastern Europe and the Mediterranean region, many of which experienced important adjustments of their channel systems, including major avulsions and increased lateral erosion (Perșoiu and Perșoiu, 2018; Brázdil et al, 2012; Barriendos and Rodrigo, 2006; Benvenuti et. al., 2008). Based on historical reconstructions, the lower course of Siret River appears to have evolved in this period from an active single-threaded, highly meandering channel to a multi-threaded anastomosed river, which is a rather common fluvial pattern for the lowland landscapes of those times (Lewin, 2010). The later succession of dry/wet or warm/cold spells has likely had great impact on the transport capacity and stability of river branches, determining additional reconfigurations, such as channel abandonment or changes of the main course (from one branch to another). Such an event may have been triggered during another documented episode of heavy precipitations and increased flood frequency which occurred in the first decades of the eighteenth century, when the lower course of Siret was affected by a devastating flood which caused significant damage in the riverine communities (1724):

‘In the same year, in the month of September, heavy rainfall started that brought waters high outside their measure, as once came, and drowned many animals and people ... hives, meadows, men and lots of children; thus came the Siret, without warning, surprising the people in houses; those who climbed up in the trees, escaped. Herds of mares were dragged by the water and few get away, flocks of sheep and poor people’s houses were altogether drowned. All the villages along the Siret look like were looted by the Tatars; because of the plenty of losses, their inhabitants will not easily forget it’ (Cronicele, 1874).

The relationship between man and the natural environment in the late medieval and early modern period was hardly conservative either. The economic significance of mills, mill fords and fish ponds

in Moldavia increased in the sixteenth and seventeenth centuries and a large number of charters recorded their presence in the area. Mill building and maintenance typically involved multiple hydraulic alterations of the watercourses, including bank clearings, channel diversions, the creation of millraces, building small dams and ponds. These works reduced the water discharge on the main channels, changed the river gradient and created conditions for silting and flooding, which were emphasized occasionally in various disputes. In 1643 the Moldavian ruler denounced the establishment of some Wallachian mills on the Lesser Siret - a frontier watercourse at the time, as their ponds partially extended into the Moldavian territory, flooding nearby meadows and gardens (DRH A27, 164) . However, this type of conflict was more frequent in the settlements located along the rivers with higher density of mills ('mill staircases'), such as the Upper and Lower brooks of Putna, where the upstream facilities were periodically affected by the downstream ponding. For example, a legal debate in 1634 indicates the presence of a succession of no less than four mill ponds in one village, which mutually restricted their functionality (DRH A22, 146).

Contiguous with the economic interests other intended interventions on the rivers had strategic grounds. In the floodplain region, the first references date from the fifteenth century, when the Moldavian sovereign Stephan the Great diverged the Siret in front of an unnamed Wallachian fortification (prior to July 1471) and diverted a 16 km long branch from the main course of Milcov, probably on a former river bed (c. 1482). Nevertheless, it can be assumed that this type of interventions, involving high costs, remained relatively uncommon and produced little effect on the overall dynamic of rivers.

Additional unintended hydrologic changes were triggered by the clearing of the regional forests, especially in the physiographic units prone to erosion. The process was related to the upstream progression of cropping and grazing in the fifteenth and sixteenth centuries, with a certain delay compared to Western Europe (Williams, 2000; Giurescu, 1980). Considering the percentage of herbaceous taxa in the local pollen records, significant expansion of pastures occurred in the Carpathian foreland after 1500, probably due to a rather radical deforestation. This perturbation can be explained to a low degree by demographic factors, and should instead be linked to the Ottoman economic control in the Romanian Principalities and the increasing demand of the Empire for timber and sheep (Filip and Giosan, 2014). The persistence of unsustainable economic activities, such as forest clearing and overgrazing in the upper river catchments led to severe soil erosion and, subsequently, to higher sediment yields. For example, it is estimated for the times of the Little Ice Age that the suspended sediment load at the scale of the entire Danube basin was 80% higher than under present-day conditions, and the increased sediment load determined the rapid development of a new lobe in Danube Delta around 1740 (McCarney-Castle et al., 2012; Mikhailova and E.A. Levashova, 2001).

Prior to modern times and the agricultural amelioration carried out in the post-Second World War period, the floodplain was also largely covered by floodplain forests, groves, shrubs and meadows, alongside endless back swamps and numerous of water bodies. In order to open space for new villages and to expand crop fields, the settlers were freely allowed to clear-cut the natural vegetation and most of the communities developed inside glades. The analysis of the recorded place names provides an insight on this long lost quasi-natural landscape, hardly remembered nowadays. Some are related to the former vegetation cover, such as Poienile Sasului (the German's Glades), Dumbrăviţa (Little Grove), Crângeni (Grovers), Branişte (Forest Reserve), Jugastru (Field Maple), Soci (Elderberry), Cătina (Seaberry) or Rogozu (Sedges), while other evoked hydromorphological details – Maluri (Riverbanks), Gârleşti (At the Rivulets), Vădeni (Village at the Riverford), Prival (Cross Channel), Nămoloasa (Mire), Belciug (Oxbow Lake), Zătonul (Channel Lake), Cracu (The Branch) or Furceni (People at the Fork, river bifurcation). It is likely that the

systematic alteration of the floodplain environment in various time periods, starting with the changes in the forest cover, enhanced flood effects and rivers instability to a significant extent.

At different scales, channel and hillslope processes were clearly affected by climate variability and anthropogenic activities during and after LIA. Precipitation reconstructions, the inventory of historic floods and pollen analyses indicate for the sixteenth century that relatively moderate precipitation and infrequent destructive floods were coeval with significant forest perturbations in the Subcarpathians (Fig. 6). This may have generated increased runoff and sediment overloading of the upper and middle reaches of the rivers. The cooler and wetter phase at the end of the century, associated with flood events of higher frequency and/or magnitude, most likely enhanced the overall discharge regime, increased lateral channel change and deposition rates in the lower reaches. Alluviation of the north-western part of the floodplain eventually assisted the flow diversion of Siret in the early seventeenth century towards the less elevated channel of Bârlad. Conversely, the hydrological regime of the warm and wet episode of the mid seventeenth century augmented channel incision and led to the disconnection of Siret's main anabranches in the former bifurcation point, sometimes before 1700.

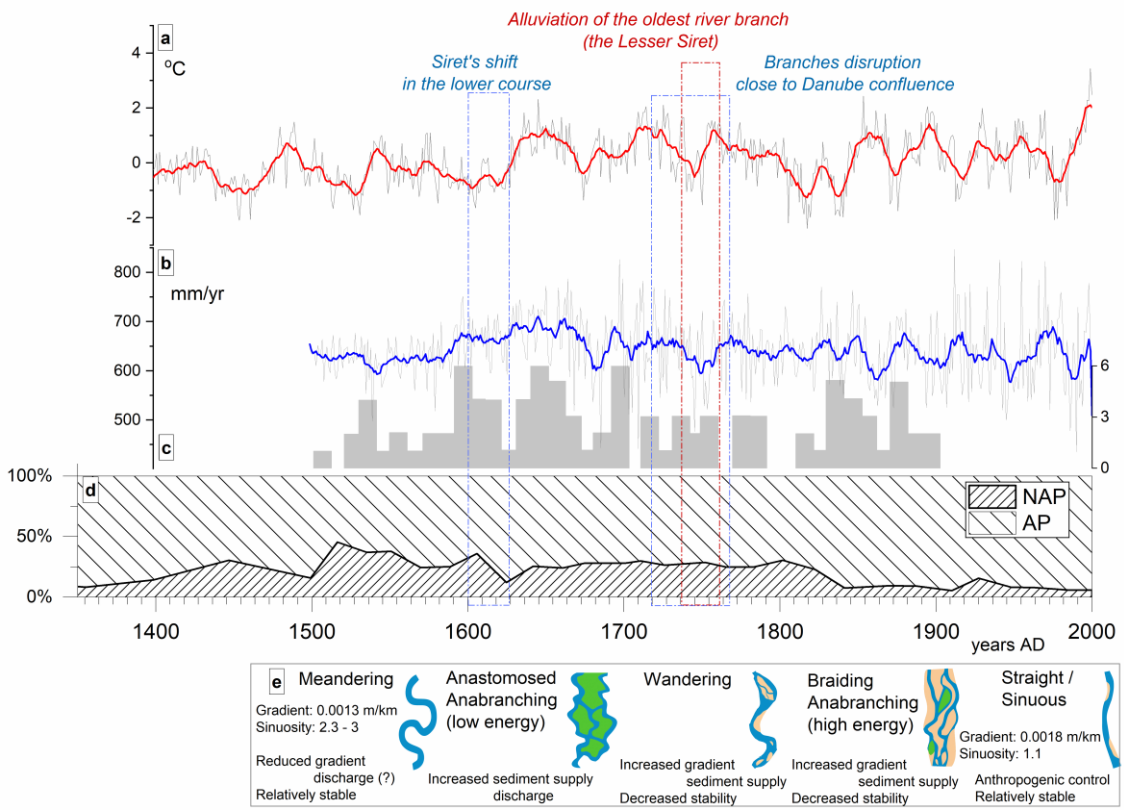


Figure 6 Paleoenvironmental records in the Lower Danube region for the last half-millennium. Blue and red dash-dotted bars indicate hydrographical changes identified in this study and their presumed occurrence periods. The red and blue lines are the 10-years moving average of (a) summer temperature reconstructions from the Eastern Carpathians from Popa and Kern, 2009 and (b) yearly reconstructed precipitations for the Romanian lands from gridded data of Pauling et al., 2006; (c) indicates a decadal flooding record for Transylvania from Perșoiu and Perșoiu, 2018; (d) diagram showing the variation between arboreal (AP) and non-arboreal (NAP) pollen grains in Subcarpathians, a proxy for grazing pressure (Tanțău et al., 2009) and (e) a dynamic of planform patterns for Siret River upstream the confluence with Bârlad and explaining hydromorphological alterations.

A subsequent episode of excess sediment storage should be associated with the infilling of the older river channel, supplied at that time by most of the Carpathian and Subcarpathian tributaries and intensively used by the watermills. This period, broadly encompassed between 1740 and 1770, is related to a cooler and relatively drier episode which reduced the transport capacity of the river, supporting the fact that climate variation and frequency of large floods controlled at least in part the alluvial activity of the main rivers. Sediment accumulation and channel clogging were, however, stronger in the mill ponds and at the confluences with Subcarpathian tributaries (such as Râmna and Milcov rivers), where geological conditions and water management activities were favourable factors. Following the disappearance of the Lesser Siret, the former side streams prolonged their channels to the lower base level of the newer course, deeply entrenching into the alluvial deposits of the floodplain. The incision process, which probably started in the eighteen century as a response to a natural disturbance, continues to date and is emphasized by the increasing human interventions, including floodplain draining, artificial diversions, embankments and gravel mining.

Recent morphological alterations were acknowledged in various studies. In case of the Lower Siret, these are primarily linked to hydro-engineering projects from the 1970s and in-stream mining. They include increased channel incision and the transformation of the previously braided pattern, typical from 1891 to 1970, into a narrower, single-thread channel configuration (Salit et al., 2015). Similar trends have been noticed also for the lowland reaches of the Carpathian and Subcarpathian tributaries, with a more stable meandering pattern. Putna experienced a 1-m-deep incision between 1960 and 2010 in the lower course (Rădoane et. al., 2013) and the average channel widths of Milcov and Buzău decrease by 43-69% between 1980 and 2005 (Grecu et. al., 2014).

5. Conclusion

Historical data provides valuable information for the reconstruction of the various features and changes of past environment. However, for the Lower Danube region reliable geographical observations are rather scarce and are typically available solely from the eighteen century onwards. For the earlier period some indirect data is provided by charters, which are increasingly preserved since the fifteenth century. The major advantages of these sources reside in the high quality dating control, the defined spatial coverage and, occasionally, the precise description of the landscape settings. Their spatial significance, however, comes with the need for a large number of observations to provide information over an extended area, which is a difficult task to accomplish in most cases.

Due to the economic or strategic significance of water resources, most of the settlements in the region developed along the major waterways. Considering the river names mentioned in various charters, the site locations and the pattern of the paleo-drainage imprints in the north-eastern part of the Lower Danube Plain, it appears that the hydrography and the associated riverscape changed significantly in the last half-millennium. In the fifteenth and sixteenth centuries, the main tributary of the Danube – river Siret, had a more sinuous course and was located westward compared to its present path, while its current side stream – river Bârlad, flowed parallel to the Danube. In the seventeenth century the former riverine settlements and lakes of Bârlad started to be placed along Siret, suggesting a shift of the latter watercourse (sometime between 1600 and 1638/39). The former channel, namely the ‘Old Siret’ or ‘Lesser Siret’, continued to collect most of the Carpathian tributaries until the first half of the eighteenth century, when it was silted. Although these changes can be broadly correlated with well known climatic episodes of LIA and

intervals with increased flood frequency in Central Europe, the fragmentary data does not support a conclusive climate-related analysis of the triggering factors. Nonetheless, some general connections with natural conditions and human activities generating hydrological perturbations and increased soil erosion may be suggested. The first intended anthropogenic alterations of the regional riverscape date back to the end of the Late Medieval Period, whereas the strongest human impact occurred from the nineteenth century onwards. It can therefore be assumed that hydrological and morphological changes occurring before the fifteenth century were dominantly driven by natural factors, such as climate change or tectonics.

The shift of the lower course of river Siret at the beginning of the seventeenth century resulted in several other alterations of the hydrological and hydrographical features, such as adjustments in the slope and concavity of long profiles, channel planform changes, supplementary channel shifts of the tributaries or increased incision into the floodplain. Minor changes, mainly anthropogenic, were documented since then, and the present configuration of the hydrographic network seemingly dates, with few exceptions, from the first half of the nineteenth century.

The interdisciplinary analysis of the available historical sources and GIS based reconstructions of the paleofluvial traces provided novel insights into the hydrographic changes which occurred in the Lower Danube region. As shown, the lack of direct environmental observations for the pre-eighteenth century period can be partially overcome by using indirect and sparsely distributed details provided by charters. Interestingly, some of these indicated that many details of the regional maps drawn by the early nineteenth century are chronologically inconsistent.

The established scenario highlights the sensitivity of the lowlands to natural and anthropogenic disturbances during the Little Ice Age and their potential for future historical environmental studies. Further research should expand the knowledge related to the detailed chronology of alluvial records in order to better understand how and why fluvial systems change.

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