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DROUGHTS, DRY SPELLS AND LOW WATER LEVELS IN LATE MEDIEVAL HUNGARY (AND SLAVONIA) III: POTENTIAL DRY SPELLS AND THE DROUGHT OF (1516-)1517

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Abstract

As a continuation of the series about droughts in late medieval Hungary, we present, analyse and compare further cases, based on contemporary direct and indirect documentary source evidence. The data, concerning (potential) low water-level conditions in 1375, 1378, 1393-1394 and 1517, and the economic problems (and solutions) probably related to multiannual dry (spring, summer?) conditions, recorded in the 1410s and 1420s, are further compared to the recent tree-ring based hydroclimate reconstruction of the OWDA (Old World Drought Atlas). Whereas the cases in 1371, 1375, 1378, (1414-)1417 and 1427-1428 (and before) reflect on local-regional problems and also show some conflicts between documentary and tree-ring based reconstructions, in 1393 the local data and the potential Danube low water-level evidence mainly reflects on lower precipitation sums in Western Hungary and the Upper-Danube catchment. The 1517 case, however, presumably refers to large-scale drought problems in the Carpathian Basin and beyond. Beyond the case studies on individual years or multiannual periods, indirect indicators of drought and dry spells are discussed and main groups of most frequent (potential) indicators defined. Preceded by a hard winter, the year of Reformation stands out both in documentary and tree-ring evidence as an outstanding drought year, and has particular importance in the paper.

Keywords: late Middle Ages, dry spells, low water levels, Danube, Sava, documentary evidence, OWDA

INTRODUCTION

In the present paper six cases – reflecting on actual dry conditions, and probably, in an indirect way, referring to dry spells that occurred in the Carpathian Basin – are discussed based on direct and indirect contemporary documentary evidence, and compared to the tree-ring based annually-resolved summer precipitation and spring-summer soil moisture reconstruction of the Old World Drought Atlas (hereafter OWDA; see Cook et al., 2015). The sources of the seventh case reflect on a significant or potentially outstanding drought, around (1516-)1517.

The discussed indirect cases from 1371, 1375, 1378, (1414-)1417, mid-/late 1420s, and the different groups of potential indirect evidence – related to drought years mentioned in the previous two papers (Kiss-Nikolic, 2015; Kiss, 2017) – are mainly based on reports that may indirectly reflect on drought or prolonged dry conditions. A common characteristic of these indirect water-shortage/deficit or dry-spell reports is that all reflect on years when the tree-ring based OWDA evidence, referring to (spring-)summer hydroclimate conditions, show notably dry conditions or even significant drought.

The last case from 1517, with potential, indirect evidence also for 1516, concerns a drought event, where both direct and indirect documentary as well as tree-ring evidence suggest outstanding dry conditions of possibly (or at least) biannual duration. This case is comparable to the greatest drought years of the period between 1450 and 1550, namely to 1473(-1474) and 1540.

SOURCES AND METHODS

In the present paper in all of the cases legal evidence, charters are utilized, mainly related to different economic (or military) activities, strongly dependent on water supply, and partly to more general, larger-scale problems. Consequently, the case studies of the present paper partly refer to drought-related economic problems detected in a relatively small area, in the neighbourhood of a village, while other cases, but especially the one in 1517, discuss severe, possibly countrywide drought problems. Thus, the present study differs from the previous ones not only in the proportionally high relevance of indirect evidence, but also because all the (potentially) drought-related information comes entirely from legal-administrative documentation, charters and (official) letters. References on possible dry spells occasionally, 'randomly' appear in charters, and can equally reflect on 'simple' dry spells or more significant drought events, while even outstanding droughts remained unrecorded. Even more indirect evidence is harvest and market-price reports and food-shortage data in years without other destructive extremes (e.g. plague, late frosts, hard/long winters).

Apart from the legal documentation where, in most cases, only the terminus-post-quem dating of a weather-related event, dry spell or drought is known, many of the cases – discussed in the present paper – refer to perambulations, field surveys, where the exact date, the name and location of the landed possession and, within that,

Fig. 1 Locations and regions, mentioned in the paper (outside of present-day Hungary, modern names are provided while names before 1920 are given in brackets; medieval counties are marked by Italics)

the approximate locations of the observation are provided. These 'metadata' help, almost in all cases, in deciding whether the dry conditions described in the charter could be a general environmental characteristics of the area or there might possibly be a sign of (prolonged) dry conditions. Furthermore, the (1516-)1517 drought event was documented in royal correspondence: charters of royal order and an application to the king.

Concerning geographical locations, all placenames, mentioned in the paper, are presented in Fig. 1. With regards to dating, similar to the previous two papers of the series (Kiss-Nikolić 2015, Kiss 2017), the original, Julian calendar dating is applied, while the modern, Gregorian calendar (hereafter GC) dates are added in brackets.

Regarding the application possibilities of the tree-ring based OWDA hydroclimate reconstruction, especially while discussing 14th-century events, further circumstances have to be taken into consideration. As discussed by Kiss (2017) in more detail, the tree-ring evidence available from the Carpathian Basin comes from the north, mainly from the mountain area of present-day Slovakia (Prokop et al., 2016). However, from the 14th and early 15th century, only a few tree samples are available, and apart from that, the OWDA reconstruction is based on extrapolated (neighbouring areas and Europe) data. Thus, the reconstruction uncertainties in the 14th and early 15th centuries are significantly higher than in case of, for example, 1517, and this can particularly affect the reconstructed magnitude of extremes.

RESULTS

Dry spell or not? Mill in very dry place: late summer 1371

On 29 August (GC: 8 Sep) 1371 a land estimation and the introduction of the (new) owners to the landed possession in *Sybolth* (Zsibót) took place in Baranya County in the South-western Transdanubia (W-Hungary; see Fig. 1). The landed possession was located at the "River" *Alma*, the present-day Almás-patak (stream), and among the listed cultivated land and immovable properties, a (water)mill with one wheel near to the borders with *Patafeulde* (Patafölde) – presumably towards the present-day Basal, to the south-west – was mentioned, located at the *Alma*, in a driest place ("*in loco siccissimo*").

In this description it is rather interesting why a mill would stand in a very dry place. One possible explanation is that the mill was out of use for a longer while, and the stream changed its bed in the meantime, leaving the mill without water. However, alone in itself, this would not explain the "very dry" conditions, and if the mill was out of use, then possibly this condition, significantly lowering the value of the object, would have been mentioned in the charter. Another logical, even more likely explanation is that the mill was functioning, but it was a temporary mill, only working in part(s) of the year, when there was much water in the streambed, while in drier periods it stopped working until the next high-water or flood episode started. This would explain no water at the mill, or even the combination of the two explanations, but being the "driest location" emphasised, a most likely option is that in the time of the land survey dry spell or drought prevailed in the area.

According to the OWDA, in (spring-)summer 1371 there was drought in Western and West-Central Europe, and in the western part of the Carpathian Basin were also dry or very dry (Fig. 2). Similar picture is presented in the documentary evidence available from then neighbouring countries and Central Europe: the May was very dry in Bohemia with frequent fires, but already the winter was quite mild, just like in Mainz, where the summer was described as very dry (Alexandre, 1987; Brázdil and Kotyza, 1995). There was great drought in Piacenza, Florence and the entire Toscana, with many "*pro pluvia*" processions in mid-/late August, and a lightning struck the church spire in Posnan (Malewicz, 1980; Alexandre, 1987). In this year, similarly mild winter and drought were reported in Russian sources (Klimenko and Solomina, 2010).

Temporary watermill stops working: January 1375

On 8 (GC: 17) January 1375 a land and property survey took place, amongst others, in *Berench* (Rétközberencs) along the River Tisza, in the Great Hungarian Plain, today in North-eastern Hungary (HNA DL 96492/1,2; Piti, 2010; see also: Vajda, 2012). While listing the properties of the village, a watermill was mentioned that operated over a waterflow in times of flooding. However, because of the lack of water, it did not work in the time of the property survey. The survey also affected other landed possessions in the neighbourhood: a dried-up ditch with three weirs is described in the area of *Monoros* (Tiszamogyorós), similarly located in the Rétköz, the floodplain area of the Upper-Tisza. The charter also reported on dry mills in the surveyed areas where, instead of water, animals were used for energy supply: one of these dry mills was located in *Berench*.

Before the mid-/late 19th-century river regulation works, this low lying area along the Tisza was prone to floods, and the village was surrounded by wetlands that usually provided high protection against unwanted visitors. Examples of significant flood events were also reported in the Rétköz area in the mid-/late 14th century, in 1342, 1345 and 1381 (Kiss 2019a). The watercourses of this area are under the influence of the River Tisza, whose lowest water levels usually occur in mid-/late summer and early autumn, and medium (but not low) water levels are typical in January (Lászlóffy, 1982). Thus, the report does not necessarily reflect on a drought. Nevertheless, as winter high waters/floods were not unusual in this area, and the ditch/watercourse in the neighbourhood, used for fishing, was also dry, we can still state that dry conditions prevailed around and before mid-January in this year. This is also interesting, because just a year earlier, due to exceptionally abundant winter rainfall, the winter-spring of 1374 became famous of great floods in Europe (e.g. Alexandre 1987; Kiss 2019a). Winter floods also affected Hungary, even if probably the contemporary source referred primarily to the Danube area (see Kiss, 2019a).

Regarding the weather conditions of the neighbouring countries, no information is currently available from the winter of 1374 and 1375 in the Czech Lands, Poland, Austria, Germany and the Byzantine Empire (Malewicz, 1980; Rohr, 2007; Telelis, 2008; Glaser, 2013). However, great drought was reported in Liège and Mainz in later spring and summer (Alexandre, 1987), and droughts were documented in Russia in the mid-1370s (Klimenko and Solomina, 2010). Although the differences in climate mechanism make any relationship occasional and somewhat indirect between the two catchments and regions, it is still worth mentioning that low Nile floods were reported by Byzantine sources in both 1374 and 1375 (Telelis, 2008).

As our study area is located in the north-eastern part of the Great Hungarian Plain, and in the north-eastern part of the Carpathian Basin the influence of the hydroclimatic

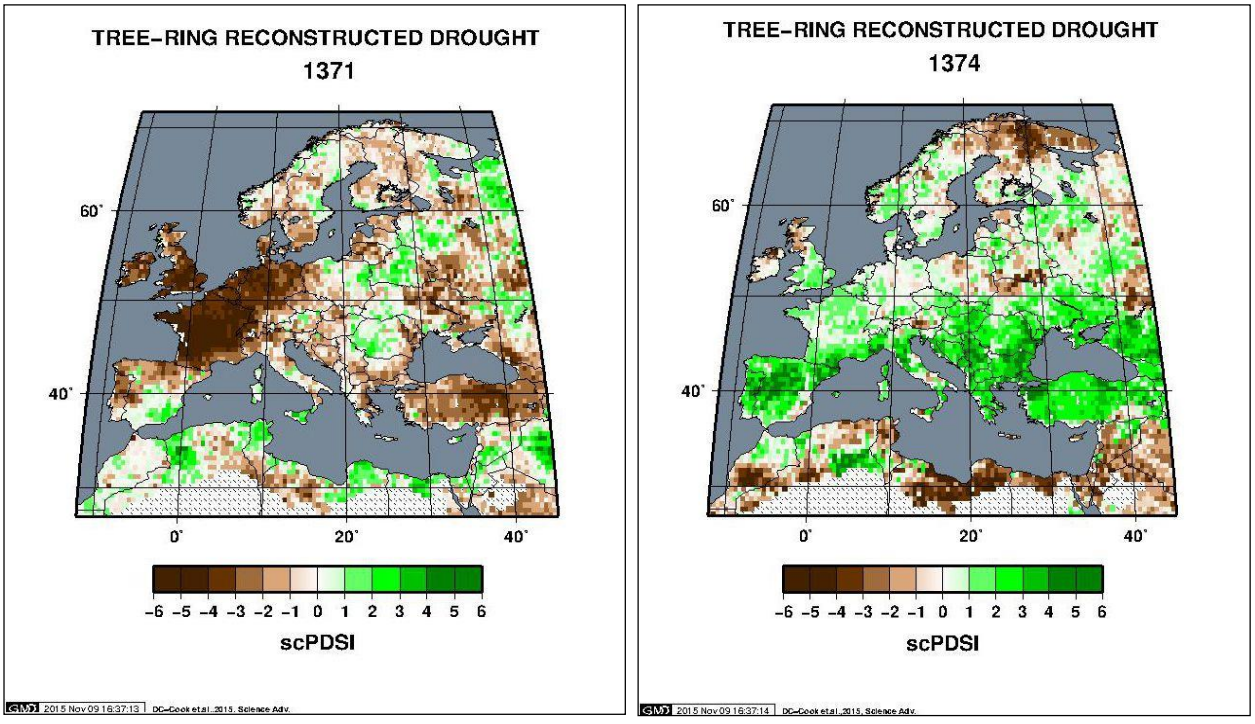

Fig. 2 The OWDA reconstruction for the years 1371 and 1374 (Cook et al., 2015; Old World Drought Atlas Data on NOAA)

influence of the regions north-east to the Carpathian Basin are also relevant, it is possible that – similar to the situation in the Eastern European Plain – overall dry conditions prevailed in the mid-1370s, and also in winter 1475. However, based on the available data, regarding our case study, we can only conclude that a dry spell was observed and described in the Rétköz area in January 1475.

As for the north-eastern parts of the Carpathian Basin, both in 1374 and 1375, the OWDA shows overall somewhat different, drier patterns compared to the rather wet conditions in most of the Basin in these two years (see Fig. 2). There is also a tendency from wetter (1374) to drier (1375) conditions in these years. Moreover, the summer and winter half years could have rather different precipitation and hydroclimatic patterns within the same year.

Water body dried up due to great drought: spring 1378

The location of the next report is east, north-east from the January 1375 report, in the north-eastern part of the Great Hungarian Plain, between the Szamos and the Tisza, but nearer to the River Szamos, in an area criss-crossed by many watercourses, dependent on the water supply of the two main rivers. Related to a debate over the ownership of *Chazlou* (Császló) landed possession, a perambulation took place on 31 March (GC: 9 April; see Fig. 1). During this field survey (Nagy et al., 1878), the perambulators also described the properties that belonged to the landed possession, and noted that the local water body dried up in time of great drought, as this water body did not receive water from other water bodies (called "*er*[*d*]"), as they found it there ("*…., et aqua, que tempore siccitatis magne ex eo, quia deriuaciones ab alys aquis Erd dictis ad se faciendas non habent, solent exsiccari, in facie ipsius possessionis reperissent*").

Although mentioned in general, the text rather describes the (great) drought as a condition what the perambulators experienced during the field survey. Before the 19th-century water regulation works, this area was criss-crossed by smaller and larger water channels. The desiccation of a (stagnant) water body, having no direct only indirect connection to the main rivers, still required low groundwater-level conditions in this area, and since groundwater levels are dependent on the water-level conditions of the Rivers Szamos and Tisza, the drying up of a stagnant water body indirectly reflects on the low water-level conditions of the two major rivers of the region.

For the North-eastern Great Hungarian Plain, and particularly for the region where Császló is located near the River Szamos, the OWDA suggests moderate dry conditions for the (spring-)summer period of 1378. Nonetheless, in the areas east, north-east to the Carpathian Basin, especially in the territories of today's Ukraine, the OWDA suggests a significant drought for this summer (Fig. 3). Furthermore, in both 1377 and 1379 the OWDA presents significant droughts (Fig. 3; Cook et al., 2015). However, the dating of the charter is clear, and also the course of the legal debate makes the 1378 dating unambiguous. As the field survey took place in early/mid-spring, it is rather possible that still the water-deficit conditions of the previous year continued in this area, and the charter in fact largely also reflect on the problems started at least in 1377.

Based on documentary evidence from the neighbouring countries and (Central) Europe, in Austria, the Czech Lands and Poland, no information is available regarding 1378, but in (late spring) 1379 there was great drought, the ditches were dry in Pomerania (NW-Poland); Miechów and Radomska towns burnt down and there was

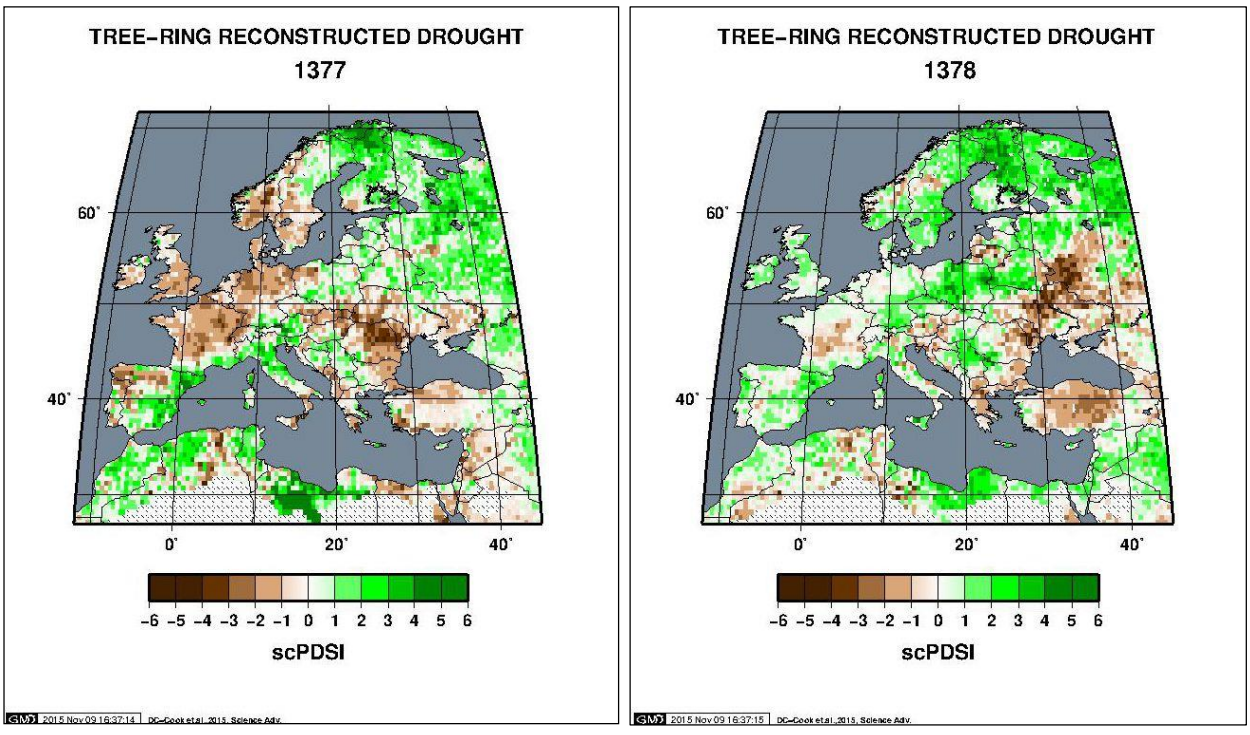

Fig. 3 The OWDA reconstruction for the years 1377 and 1378 (Cook et al., 2015; Old World Drought Atlas Data on NOAA)

great (summer) drought in the kingdom of Poland (Malewicz, 1980). While no weather-related evidence is available from the Balkan area regarding 1378, the high level of watercourses was reported in mid-April in the Arnhem area (E-Netherlands), and in late March the abundance of snow was reported in Vicenza, North-eastern Italy that stayed for a longer period (Alexandre, 1987). Beyond that, only the early March great frost at the Bodensee is known from the year (Alexandre, 1987; Glaser, 2013).

Potential signs of the 1393 drought in medieval Hungary

In 1393 great drought was described by a number of contemporary sources in Central and Western Europe (e.g. Alexandre, 1987; Brázdil and Kotyza, 1995; Rohr, 2007; Glaser, 2013). Moreover, both based on documentary and the OWDA evidence, approximately in the same regions of Europe as in 1393, the drought continued in 1394 (see Fig. 4), while the Nile – just like in 1374 and 1375 – also had low flood in this year (Telelis, 2008). Contemporary charter evidence may also provide indirect parallels in the Carpathian Basin to this great drought event, even if the tree-ring based hydroclimate reconstruction of the OWDA only suggested drought in the western, north-western and the most north-easterly parts of the Carpathian Basin for this year. No direct contemporary reference is available in medieval Hungary that would mention this drought. However, some indirect evidence may increase the chance that this drought affected larger areas in (Western?) Hungary, too.

An early harvest reference is available from March 1394, dating the illegal harvesting of grapevine prior to 8 (GC: 17) September 1393 in Kál, north to Lake Balaton, in the Central Transdanubia (HNA DF 200361; Kiss, 2016). Although this is primarily a temperature-related information, great droughts are usually accompanied by higher temperature values and earlier harvests (see e.g. Wetter et al., 2014; Kiss, 2018; Camenisch et al., 2019).

In November 1393, a court hearing took place: the abbot of the monastery of Elefánt (Lefantovce-Sk) blamed the noble neighbours for causing water deficit to the watermills of the monastery with diverting the course of the mill canal of the River Nitra (HNA DL, 7902; Mályusz, 1951). Although the abbot presented as a fact that the water was diverted, as no further part of the legal debate is known, it is not possible to decide whether the abbot was right in blaming the neighbour, and in what extent the neighbour can be blamed for the water deficit. However, in another case, in 1422, when the abbot blamed neighbouring landowners with causing destruction in the mill of the monastery, the damage was caused by the vehement flux of the river and not by human intervention (see Kiss, 2019a).

A further case concerns the Danube in 1393: similarly in November, a charter was issued containing the complains of the parish priest of *Pispuky* (Püspöki; today in Bratislava-Sk), referring to an island that changed location due to previous floods. Situated closer to *Orozwar* (Oroszvár; today part of Bratislava-Sk), the serfs of the latter domain started exploiting (illegally) the forest on the island (HNA DF, 237891; Mályusz, 1951; see also Kiss, 2019a). As usually it was easier to exploit island forests and especially to transport the wood from the island areas, in times of low water levels, it is possible that the water level of the Danube was low for a longer period in this year, providing suitable conditions for the illegal woodcutters. This is especially likely, as there was great drought in Austria in 1393 (Rohr, 2007).

On 28 June (GC: 7 July) 1394 a perambulation took place in Baranya County, in the area of today's Majs, (Nagy)Nyárád and Kölked, between the lands of the local landlord, László Töttös and the cardinal-bishop of Pécs. During the field survey and perambulation between *Laak*, *Laymer*, *Kerekyghaz* and *Maysa* landed possessions, the survey proceeded from *Lak* towards the west, along the

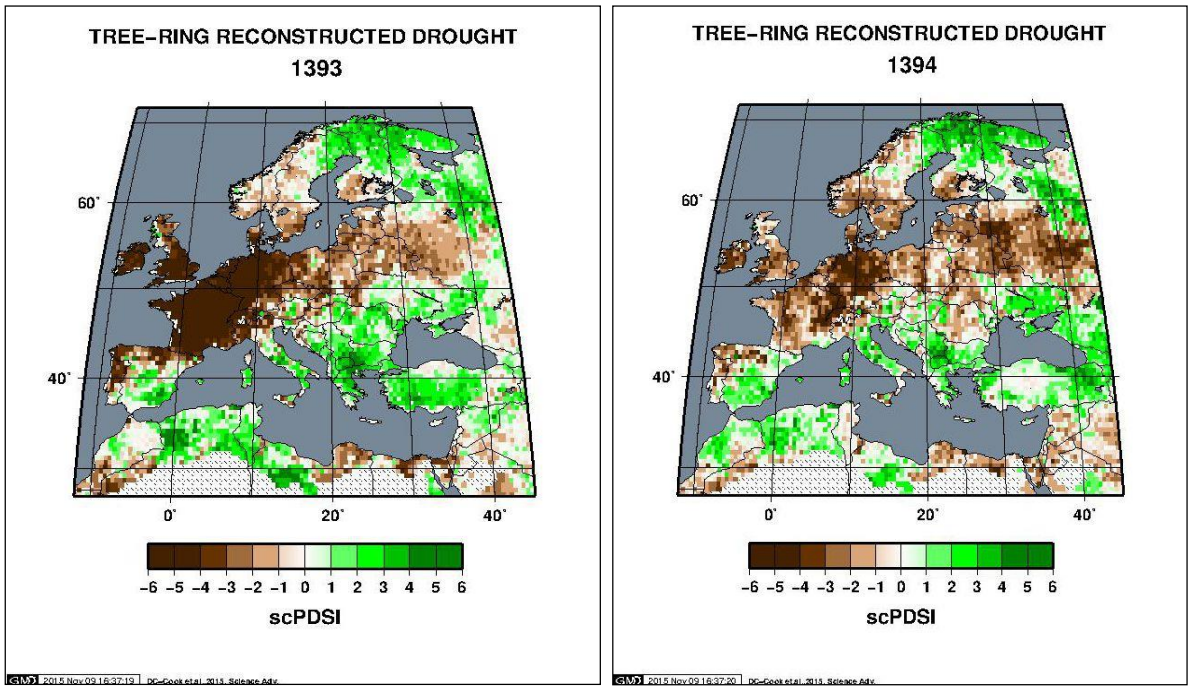

Fig. 4 The OWDA reconstruction for the years 1393 and 1394 (Cook et al., 2015; Old World Drought Atlas Data on NOAA)

big (main course of the) Danube, reached the place where the small Danube (a Danube branch) left the big Danube; here, just along the river and its branch, the charter described a dry meadow (Nagy, 1878). Taking into consideration the moderate elevation differences and low elevation conditions of the area, the mentioning of a dry meadow right along the main Danube and its branch is rather interesting, as the area is under the direct hydrological influence of the Danube.

It is also interesting that in 1395 an Italian delegate – staying in Buda and sending regular reports on his 'observations' in the royal court, the town and the country – asked his lord, the Duke of Mantua, for permission to return to Italy, because his spendings were too high, caused by the current high prices in the town (Óváry, 1890; see also: Kiss et al., 2016). Although little is known about the weather conditions and harvest results in 1394, the high prices on 27 November (GC: 6 December) 1395 might be still related to the great drought, especially because, according to the OWDA, there was also significant drought in 1394 in large parts of Western, Central and even in Eastern Europe, but drought continued in the German areas, Eastern Europe, and also in Transylvania and the Balkan in 1395 (Cook et al., 2015). However, the OWDA does not list most of the Carpathian Basin among the affected areas.

Based on the OWDA, however, the (spring-)summer drought in 1394 only affected Transylvania and the north, north-eastern (hilly) areas of the Carpathian Basin. Although the reconstruction also suggests conditions somewhat drier than usual in the western part of the country, including the Little Hungarian Plain (Kisalföld), which was the main crop supplier of Buda in the late Middle Ages (Kubinyi, 1975), this general water deficit does not reach the extent of a drought in the OWDA reconstruction (see Fig. 4). Nevertheless, if this moderate dry (spring-)summer arrived after a much drier year, theoretically the somewhat better conditions (and harvest results) could be still insufficient to provide enough food-crops to feed the entire town and its agglomeration.

In conclusion, a number of indirect evidence suggest that the 1393, and possibly also the 1394, European droughts had some impacts in Hungary, too. The indirect evidence, on the one hand, refers to the contemporary pontentially low water-level conditions of the Danube, reflecting on the great (hydrological) drought that affected the German areas and Austria in 1393. On the other hand, all other – potentially drought-related – information comes from the western, north-western part of the Carpathian Basin, where otherwise the OWDA also suggests a (moderate) drought for this year. It is not clear whether the high prices, mentioned by an Italian delegate in 1395, are still related to this drought, however, except for most of the Mediterranean, 1394 was also a drought year in most parts of Europe.

1415-1416: problematic years – full of contradictions?

In connection with a postponed legal debate in 1415, very high prices or dearth of the recent past, that had already passed, were mentioned on 30 July (GC: 8 August) in Doboka County, Transylvania (HNA DL 73953; Mályusz, 1997, see also Fig. 1). As the information comes from around harvest time, most probably the bad harvest of the previous year or years was followed in 1415 by a better one, so that the crisis was over with the new harvest.

Dated to 6 June (GC: 15 June) in the same year, a royal order (of King Sigismund) was issued in support of the parish priest of Szentpéter (today part of Cluj-Napoca-Ro), related to a mill whose utilities belonged to the parish, but the neighbouring Kolozsvár (Cluj-Napoca-Ro) town questioned this right (Jakab, 1870). There is a rather interesting sentence in this charter, stating that the serfs of the parish, in their grave poverty – as heaven took away their resources –, could not afford a coach to carry their crop harvest to the mill, and therefore for them this mill was of highest importance, as they would have been unable to travel to another, distant mill. This sentence – possibly reflecting on multiannual problems – might be particularly interesting, when we take into consideration that the parish was located in one of the richer, central parts of Transylvania. However, the situation probably becomes more understandable when taking into consideration the previous evidence on great dearth, also coming from Transylvania.

Similar problems were recorded in the next year: on 6 October 1416, Queen Barbara/Borbála (wife of king Sigismund) ordered Sopron County officials to prohibit the export of cereals (Házi, 1923). The prohibition of cereal export had been previously decided, because the king wanted to avoid the further increase of the countrywide high prices/dearth ("*caristia non modicum*"), indirectly suggesting larger-scale problems within the country.

Hardly more than a month before, on 3 (GC: 12) September 1416, a high officer of the Austrian prince sent an official letter to the town council of Sopron asking for the reason of prohibiting the export of oat to Austria (Házi, 1923). As Vienna in the late 15th century largely depended on grain import from the Czech areas and Hungary, the prohibition most probably caused shortage in resources. Moreover, the document indirectly also suggests that the royal order for prohibiting cereal export was most probably dated not much earlier, perhaps to (late?) summer, possibly responding on an overall weak harvest, and a (reasonable) fear of a(n even graver) dearth in Hungary. However, it is interesting that, despite the intensive daily trade connection, the Austrian court had no knowledge of the reasons of prohibition in Hungary. This circumstance may indirectly suggest that in the Sopron area and at the western borders of the country there was no bad harvest or significant shortage of cereals (oats in specific) in this year.

The reports on very high prices and/or great dearth in Transylvania in 1415 and then in the entire country in 1416 altogether suggest significant problems with harvests on a multiannual scale in 1415, 1416 and most probably also, at least, in 1414. As large-scale (crop) harvest problems in the country are usually the consequence of prolonged dry conditions, and sometimes also of extreme hard winter, late frosts or, even more rarely, the too much precipitation, it is rather important in finding possible explanations that, based on the OWDA, drier than usual conditions prevailed in 1414 and 1415, while 1416 was dry in the north-west, but in the rest of the country average or slightly wetter conditions were dominant (see Fig. 5).

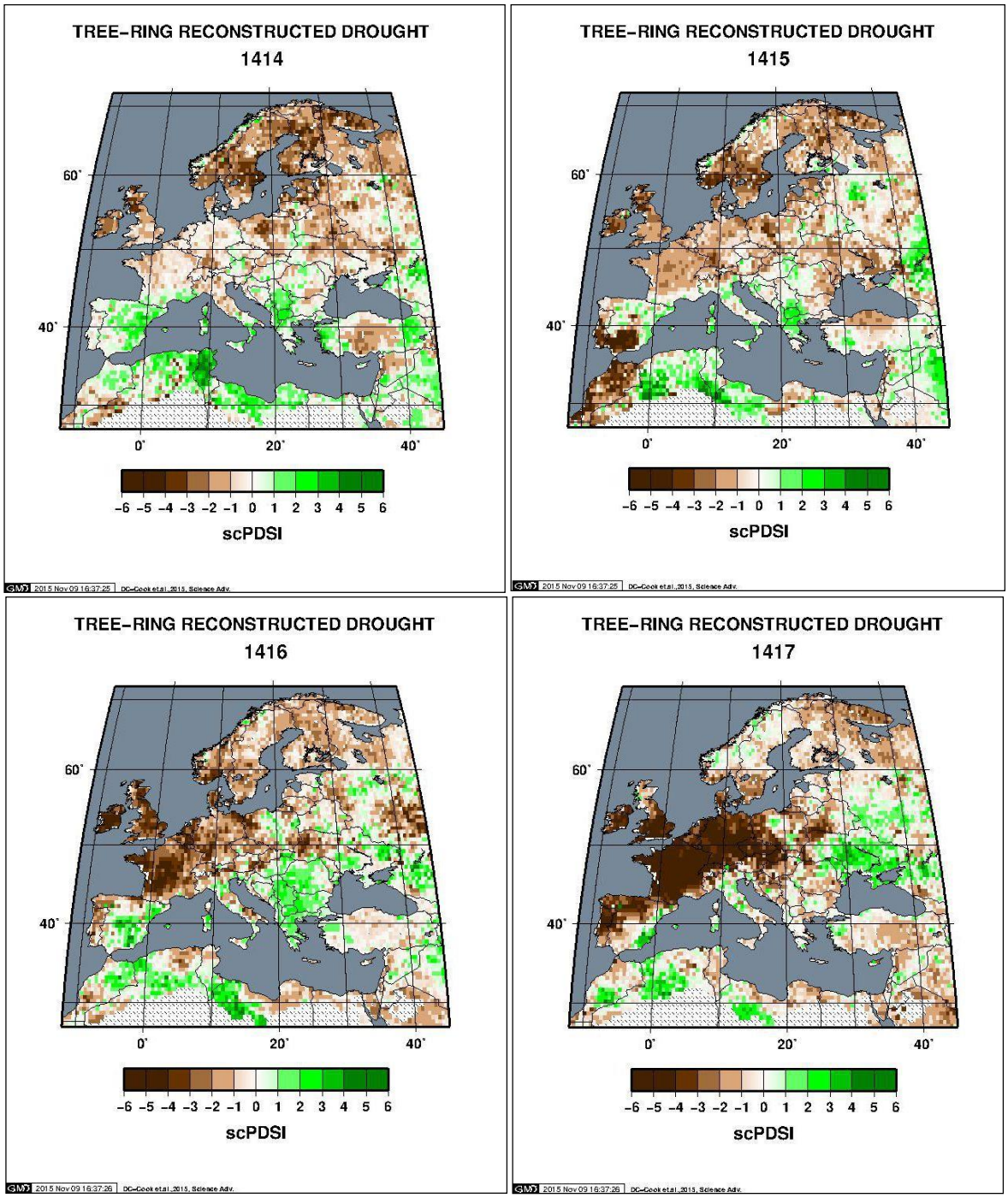

Fig. 5 The OWDA reconstruction for the years 1414-1417 (Cook et al., 2015; Old World Drought Atlas Data on NOAA)

Thus, the OWDA does not suggest for the Carpathian Basin strong drought for 1414, 1415, and in 1416 only the western, north-western part of the Carpathian Basin was dry, while the rest of the country was more wet than dry. Around average or moderately wet conditions, in themselves, are usually favourable for agriculture in the central and eastern parts of the country; apart from the temperature extremes, only very/prolonged dry and rarely prolonged very wet conditions cause problems. Furthermore, a mid-July Danube flood and a winter flood in the north-east, in the Upper-Tisza catchment was recorded in January 1416, whereas practically no ongoing floods of Carpathian Basin origin were documented in 1414-1415 (see Kiss, 2019a).

The situation what we gain from the documentary evidence of the neighbouring countries is even more complex, partly also contradictory. In Poland, for example, documentary evidence suggests rains in summer 1414, and the whole year was rather wet in 1415 (Malewicz, 1980), while for both (spring-)summers the OWDA suggests notable dry conditions (Fig. 5). Rainy summer was suggested for 1415 in Bohemia (Brázdil and Kotyza, 1995) – the OWDA suggests considerable dry conditions for the same period (Fig. 5). In Austria, summer was rather warm in 1414, but 1415 was most probably also wet (Alexandre, 1987).

The picture is similarly contradictory in other parts of Western and (Central) Europe. Based on Glaser (2013), in the German areas, after the hot and dry summer of 1414 and

the presumably average summer, no information is available regarding summers (or other seasons) until 1418. Alexandre (1987) suggests that, after the summer droughts in 1412-1414, spring-summer of 1415 was wet with inundations, floods were also reported in June-early/mid-July in 1416 in the westernmost parts of the German and the eastern parts of French territories. These descriptions clearly contradict with the OWDA reconstruction (see Fig. 5), where notable drought is presented in the same areas. (Northern) Poland was similarly wet in summer 1414 and in 1415 (Malewicz, 1980) – but, at least, in case of Poland the OWDA also suggests wetter conditions. On the other hand, in 1416 great heat and drought was described between mid-August and early October in Forli and Sienna, in Italy. Usually collected in (late June)-July, such a late-summer drought would not have affected the crop harvest in Hungary.

Thus, 1414 might have been problematic because of dry and hot weather, while in case of 1415 documentary evidence suggest wet, while the OWDA suggests dry conditions for (spring) summer 1415 and 1416 (see Fig. 5). Winters were average, cold in some parts in Bohemia and the German areas (Brázdil and Kotyza, 1995; Glaser, 2013).

In general, the 1415-1416 cases provide a rather contradictory picture. The 1415 Transylvanian reports, well before harvest time, mainly refers to problems of the previous years, especially to the dry period of 1412-1414. In 1415 and 1516, the shortage of crops inducing export prohibition might have been partly or mostly due to extraordinary wet conditions in the central and eastern parts of the Carpathian Basin. This might be also supported by an application from the western edges of Szatmár County, generally complaining on the many floods (of the preceding times), caused by the abundant multiplication of rains prior to 1417 (see Kiss 2019a). However, considering the rather contradictory, opposite patterns – presented by documentary and the OWDA reconstruction – we cannot completely exclude the possibility that also in 1415 and 1416 dry (and or cold) conditions prevailed in the first, most important spring part of the vegetation period in the central and eastern parts of the country that badly affected harvests in these years.

1417: drought or not?

The charter of the St. Stephan order in Székesfehérvár, issued on 25 December 1417 (GC: 4 January 1418), states that their *Zedregh* landed possession often lacks water in summer ("*Ceterum quia tempore estiuali sepius aqua in ipsa possessione deficeret*"), and when it happens, the other owner is obliged to provide ample water supply to the other landowner, his serfs and animals (HNA DL 105344; see also Mályusz and Borsa, 1999). According to Fejér (1844b), the landed possession, with settlement, was located in the southern part of Fejér County, between The River Sárvíz/Sió and the Danube, in the area what is today Előszállás, Alsószentiván and Nagykarácsony (see Fig. 1). The landed possession was located in a sandy wetland area, and was clearly populated at the time of the charter issue, and at least one notable local noble family also lived there. Moreover, another charter of the same survey is available from the (same) December 1417 survey (HNA DL 43377) – yet without mentioning the water deficit problem.

As the charter specifically states the summer water deficit problem, and therefore the problems has great importance for the landed possession, it is rather possible that the summer water deficit mention reflects on current (or near-past and/or multiannual) problems. The OWDA suggests significant drought for Western and Central Europe for (spring-)summer 1417. With particular intensity in the north-west, based on the OWDA, in 1417 there was also drought in the Carpathian Basin. Moreover, based merely on the OWDA, in the western part of the country dry or rather dry (spring-) conditions prevailed in each summer already from 1407 (see Fig. 5).

As for the documentary evidence in other parts of Central Europe, the winter of 1417 was memorably hard and rich in snow: both Austrian, Czech and German sources speak about the severity of this winter. In general, from Liguria through Germany to Poland, the very cold (and snowy) character of the winter was emphasised in 1417 (Malewicz, 1980; Alexandre, 1987; Brázdil and Kotyza, 1995; Glaser, 2013). In Poland the winter was so cold that crops were destroyed, and – as summer was also unfavourable for crop development – there was bad cereal harvest (Malewicz, 1980). Although the source does not describe summer conditions any further, one possibility for the cause of bad harvest might be (spring-)summer drought.

No information on this summer is available from the Czech Lands regarding the year 1417 (Brázdil and Kotyza, 1995). In Austria, the cold and snowy winter, when the Danube also got frozen, was followed by good vintage and good quality of wine that suggests warmer than average summer conditions (Alexandre, 1987). Moreover, good harvest may also suggest that, despite the hardness of winter, the winter frost did not severely damage the vinestocks (or the snowcover was thick enough).

Famine in mid-/late 1420s: any relationship to drought?

On 19 October 1428, King Sigismund gave some tax relief and further privileges to the Iasonians, because of the dearth or famine affecting them for years (*propter caristiam sive famem aliquorum annorum, post sese continuo praeteritorum*; see Fejér 1844a). Documented in mid-February 1428, most probably in the previous year the town of Nagyszőlős (Vynohradiv-Ua) in Ugocsa County, in the north-east, partly burnt down (HNA DL 70845, see Fig. 1).

In the Middle Ages, Iasonians lived in one block in Iasonia, mainly around the present-day Jászberény and Jászfényszaru towns, but also lived scattered in various regions, partly east, south-east to Pest (e.g. Cinkota; today part of Budapest), and partly along the River Tisza in the Great Hungarian Plain. Although, similar to Cumans, their main activity was animal husbandry, they were traditionally more involved (than Cumans) in land cultivation, too. The multiannual famine among the Iasonians clearly had to be, at least partly, related to unfavourable weather conditions, a circumstance that hit their traditional economy for a longer period of time. Thus, it was most probably not (only) the result of a single hard winter, late frost or any other, individual extreme event. Furthermore, as Iasonians mainly lived in the floodplains of the drought-sensitive Great Hungarian Plain, their agricultural activities strongly depended on the availability of water.

The fire incident in Nagyszőlős (today Vynohradiv in the Transcarpathian region of Ukraine) occurred in an unknown time, but not immediately before mid-February (i.e. more probably in 1427), and not the entire town but only part of it burnt down. As large scale fire events favour dry and windy conditions, in such a case there is a higher likelihood that prolonged dry and windy conditions were also responsible for the calamity. However, we have to add that chances for devastating incidental fires are also higher in hard winters and prolonged hot (and windy) conditions. Thus, drought is not necessarily a precondition.

Although rather indirectly, it might be also important that, after the autumn 1424 River Nitra flood, no ongoing floods of Carpathian Basin origin are known from contemporary documentation until 1432 (see Kiss 2019a). Naturally, the lack of flood-related documents does not mean the complete lack of considerable or even great flood in a year. Nevertheless, when less unusual floods occur for multiple years then there is more chance that floods remain unreported, and in case of a longer period without flood evidence the likelihood for generally drier conditions is higher (but not exclusively) than in other periods.

For 1427 and the years before, the OWDA suggests dry or very dry conditions. In fact, rather dry conditions prevailed in each year from 1417 until 1427; based on the OWDA, the first wetter year was 1428 (see Fig. 6). Thus, it is rather possible that the prolonged dry conditions (11 years!) had major responsibility in the multiannual food shortage problems described in the charters. Moreover, based on a royal charter, the winter of 1427 was rather (or even: exceptionally?) cold and snowy in Transylvania, when Turkish troops broke into the country and caused immense damages (Fejér, 1844a). Combined with the multiannual drought, hard winter conditions might have meant an additional stress and could increase the food supply problems.

The 'perfect match' in the year of Reformation: the great drought of (1516-)1517

Based on the OWDA hydroclimate reconstruction, in the year of the Reformation (Luther's proclamation to the bishop of Mainz: 31 October, 1517), an outstanding drought occurred in (spring-)summer all over Central and Western Europe, and already 1516 was a drought year in Europe (see Fig. 7). This reconstruction is in 'perfect match' with the information derived from documentary sources: both in direct and indirect evidence, this drought was also documented in contemporary sources in the Carpathian Basin.

In a royal order written on 19 (GC: 29) August 1517, the king ordered all judges, lay or ecclesiastical, first to suspend for 15 days and then to completely stop all legal procedures in the kingdoms of the Hungarian crown in which the Duke of Slavonia, Ferenc Hédervári, and his vassals (so-called "*familiares*") were involved, as they were at that time occupied by the defence against a threatening Turkish attack in the two most endangered counties, Valkó (Vuka-Hr) and Pozsega (Požega-Hr), in Hungary and Slavonia (HNA DL 91054; see also Fig. 1).

The fact that the two counties, located along the lower sections of the River Sava, were most in danger reflects on the one hand the location of the Turkish strongholds, but also suggests prolonged critical water shortage in the entire catchment area of the river, not only in the south-eastern part of the Alps and Slavonia, but also in Bosnia. As a potential parallel, extreme low Sava water level was mentioned in 1474: at that time it was related to an outstanding great drought, affecting the Carpathian Basin and the South-eastern Alpine area, both in 1473 and 1474 (Kiss and Nikolić, 2015; Kiss, 2017). The similarities in conditions may raise the possibility that the drought probably started already in 1516.

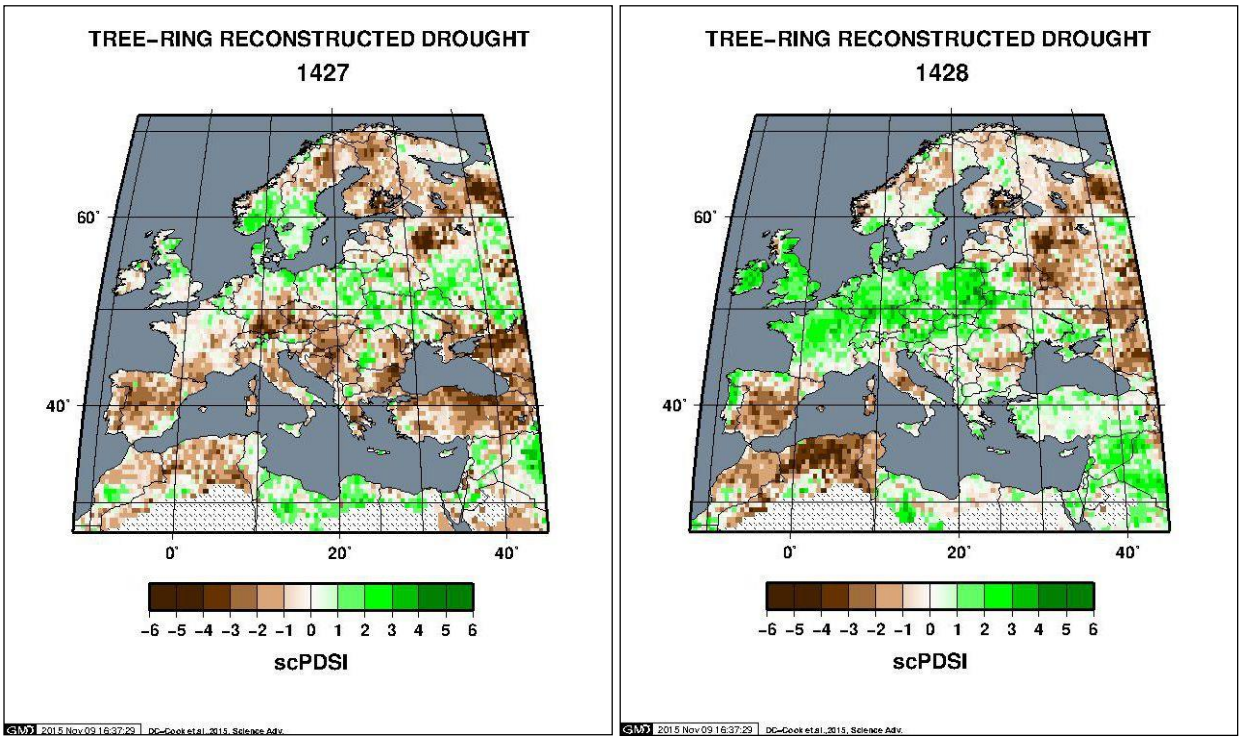

Fig. 6 The OWDA reconstruction for the years 1427 and 1428 (Cook et al., 2015; Old World Drought Atlas Data on NOAA)

Another report, indirectly reflecting on drought and unfavourable weather conditions, also suggests that significant anomalies occurred in 1517 and possibly also in early 1518. On 17 (GC: 27) April 1518, a letter was sent by the town officials of Nürnberg to the nearby Rosenburg, providing an explanation on the current high prices of meat in the German areas. According to the letter, the problem originated in Hungary: lacking fodder in winter, large part of the cattle perished that caused a shortage of meet in the German areas (Thallóczy, 1900).

Mass loss of cattle in Hungary was usually related to bad hay harvest, which was predominantly the consequence of drought. However, fodder shortage – resulting mainly the loss of young animals – might have also developed during prolonged hard winters. A multiannual drought, alone in itself, or the combination of a drought and then long hard winter could have catastrophic consequences on the cattle population.

A further, indirect evidence also suggests considerable problems: on 30 May 1517, the lead tax officer sent a report to the Duke of Slavonia and Croatia, stating that it was not possible to gather taxes from his Slavonian serfs due to their extreme poverty that was so great that many died in famine (Iványi, 1942; see also Kiss, 2019b).

Apart from the drought both in 1516 and 1517, winters of both years were, at least partly, also severe. Nevertheless, the selling and production prices, recorded in the Tokaj-Hegyalja Wine Region (in Tállya; see Gecsényi, 1966), were relatively low and decreasing in both years, indirectly suggesting that the winters of these two years were not hard enough to have multiannual negative impacts on the vinestocks and wine production.

Already the summer and autumn of 1516 was very dry, but after a hard and moist winter, the spring of 1517 was again unusually warm, and extreme dry – the driest of the century in the German areas. Heavy frost that caused great damage in the cultivated vegetation was followed by very hot and dry summer, also reflected in bad hay harvest results. However, the second decade of July brought rain and, according to Glaser (2013), rainy weather continued in August and much of September in the German areas. The winter of 1518 was suggested to be altogether normal, but with great regional differences (Glaser, 2013).

The very hot and dry character of summer 1516 is also emphasised in Bohemian sources, and in fact – just like in Poland – the entire year was dry with low water levels of the River Elbe (Brázdil et al., 2013).

DISCUSSION

(1516-)1517: comparable to the most severe droughts of 1473(-1474) and 1540?

In France, Le Roy Ladurie (2004) referred to the 1517 drought as comparable, or even more severe, than the one in 1473, also legendary in Hungary (see Kiss and Nikolić, 2015; Kiss, 2017). For the Carpathian Basin, the OWDA suggests lower PDSI index values for 1517 than for 1473 or even for the other outstanding drought, 1540 (see *Fig. 8*).

Based on the information available in documentary evidence, it is difficult to decide over the differences in the magnitude of the drought events – all three were important, but for 1473-1474 and 1516-1517 we have more direct contemporary evidence that refer to outstanding drought. In Hungary, we have no information about broad-scale food or fodder supply crisis in 1473-1474, but both in 1516-1517 and after 1540 there were significant problems documented. Both in 1474 and 1517 low water-level problems were recorded. However, only in one case, in 1517 mass perdition of cattle was reported. Based on this latter information,

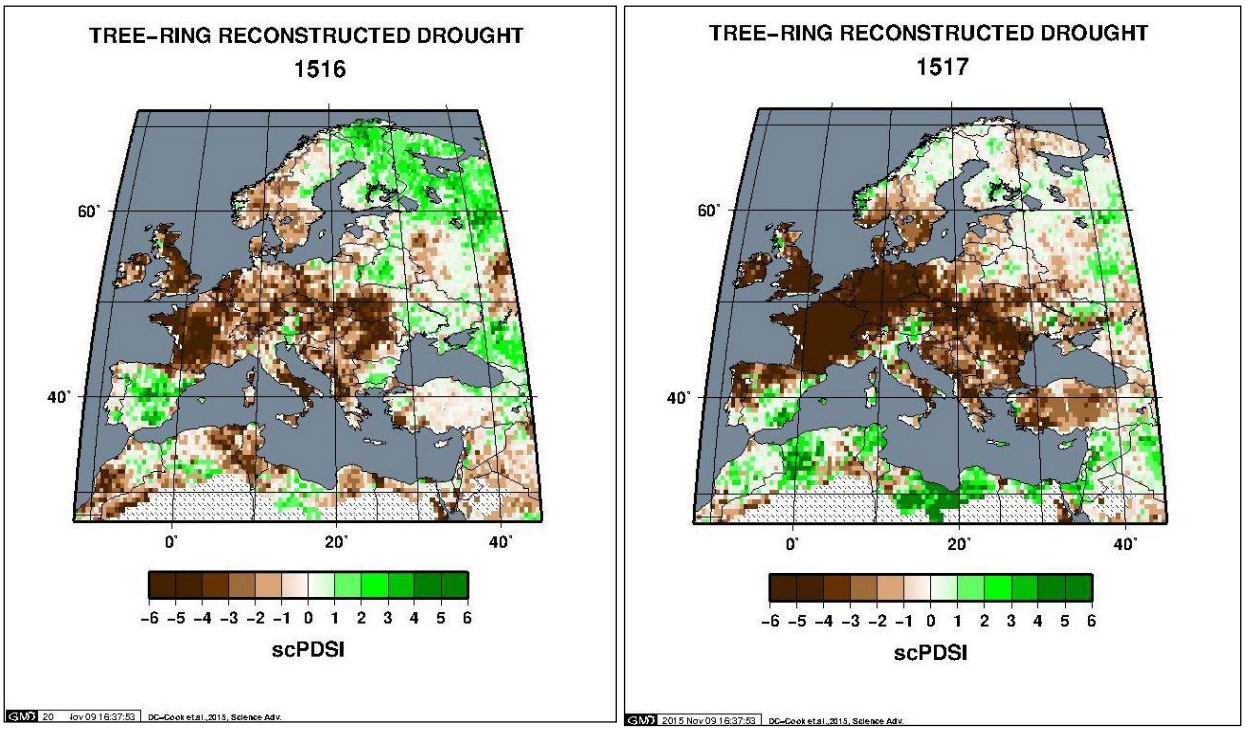

Fig. 7 The OWDA reconstruction for the years 1516 and 1517 (Cook et al., 2015; Old World Drought Atlas Data on NOAA)

probably the (1516-)1517 drought holds the most signs of an outstanding drought – this drought was also singled out as most extreme between 1450 and 1550. However, the evaluation strongly depends also on source availability.

Another, rather thought-provoking circumstance is the potential relationship between the great drought of 1517 and the previous years and the start of the Reformation. Even if the reasons for the reformation rooted in societal problems and the (moral, structural) crisis of the church, the increasing societal and economic tension within the society, caused by bad harvests due to unfavourable weather conditions, and the recurrent significant and outstanding droughts in particular, provided a favourable background to the increasing desire in the lower layers of society for considerable changes. In the earlier part of the decade (i.e. 1513-1514) this increased societal tension manifested itself in peasant revolts that affected much of Central Europe including Austria, German territories in the south, south-west as well as the Hungarian kingdom (see Kiss 2019b). Thus, even if no direct relationship can be detected between multiannual dry conditions, droughts, societal tension and abrupt changes, multiannual dry conditions were partly or mainly responsible for repeated bad harvests that could be an important contributing factor, a catalyst of societal changes. No such substantial, abrupt changes can be detected in the 1470s and around 1540, which fact also reflects on the primary importance of (long-term) socio-economic processes over the importance and influence of multiannual unfavourable weather conditions.

Potential, indirect references on droughts or dry spells

Several types of potential, indirect indicators of dry spells or drought were already listed in this and the previous papers of the series. In this subchapter a short overview of these indicators, and some additional further indicators are discussed in brief. It is important to note that most of the listed cases or problem groups did not only occur during dry spells or droughts; however, we argue that the frequency of these problems – and therefore the likelihood for documentation – is often, but not necessarily, higher than in other years. The list presented here is not exclusive – further indirect indicators may be suggested later, in due course.

Potential signs of large-scale harvest problems – often induced by prolonged dry spells or drought – could be, for example, the increased number of controversies, violence, illegal gathering or confiscation (robbery) of hay or crop harvest and the similarly illegal (crop) cultivation of other people's meadows. More hay-related problems such as robbery, violence against harvesting peasants or land-usurpation were documented in charters, for example, in 1473, 1479-1480, 1494, 1503, 1506-1507, the early 1510s or in the late 1510s and early/mid-1520s.

Based on the abstract search in the charter abstracts of the medieval collection of the Hungarian National Archives, for the period 1300-1526, currently we found 107 years when hay-related problems, negotiations, illegal acts (violent attacks, illegal activity, meadow occupation etc.) were mentioned in legal documentation at least once a year (sources: Hungaricana database). Out of these 107 years, the OWDA suggested drought or severe drought in case of 44 years, while notable dry conditions, dry spells were in 21 years. In case of other 40 years no significant dry conditions were presented by the OWDA, and only in two cases hay-related controversy was mentioned in particularly wet years. Thus, this means that in 2/3 of the hay-problem cases notable dry conditions or droughts were captured by the OWDA for the (spring-)summer period. However, it is important to emphasise that the relationship between dry conditions and hay-related controversies is far not exclusive: sometimes even in particularly wet years we can meet with such problems. Still, there is a higher likelihood for the occurrence of such problems in dry years.

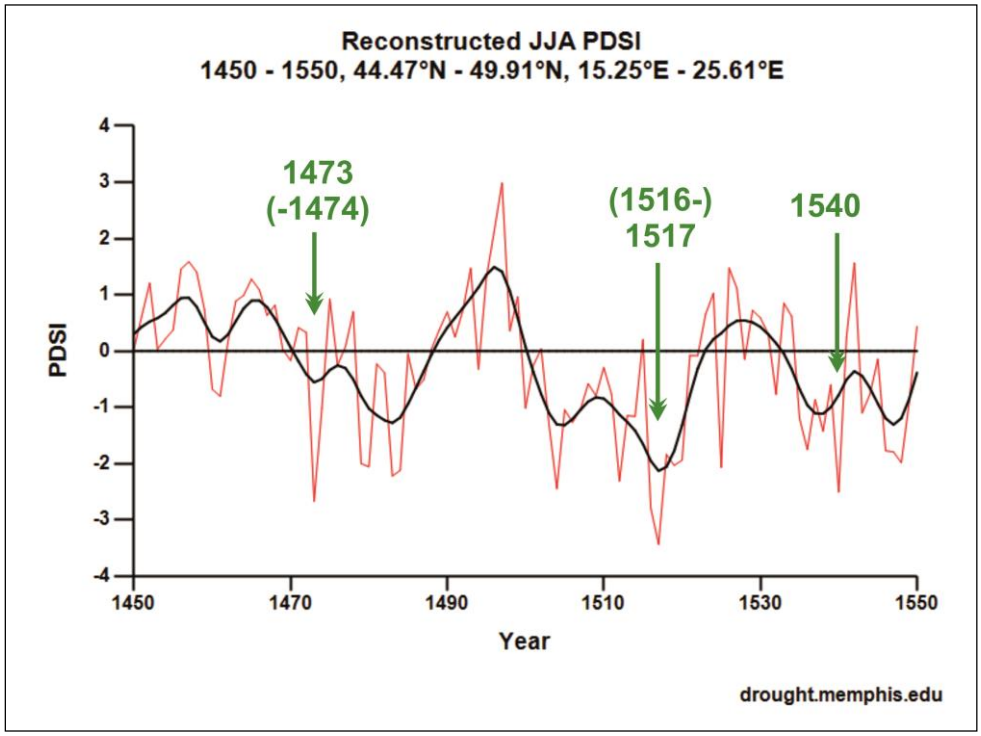

Fig. 8 The OWDA reconstruction for the years 1516 and 1517 (Cook et al., 2015; Tree Ring Drought Atlas Portal)

Rather similar results can be gathered from the same late-medieval database regarding crop-related controversies, violence and the illegal gathering of crop harvest. Based on the OWDA, out of the documented 56 years, the (spring-)summer period of 20 cases were very dry, 15 were notably dry, 17 were – on the Carpathian basin level – average, and four were wet. Thus, around 2/3 of the cases were related to dry or very dry conditions. Nevertheless, the negative influence of other weather extremes (e.g. hard winter, late frosts) as well as the impact of socio-economic processes also has to be considered, and these provide a significant bias while studying the relationship between dry conditions and harvest results. Moreover, there were also changes within the late medieval period that has to be considered: for example, the increase in documentation and the quantity of the available legal evidence (see e.g. Kiss 2019a), the growing population and export possibilities (e.g. grain) or the increasing cattle export and the need for fodder (i.e. increased importance of haylands).

A small group of cases can be related to controversies and purchasing Danube islands: as we could see before, in 1393-1394 the water level of the Danube was most probably quite low. Other interesting cases are related to island purchases: these cases lead us back to the late 13th-early 14th century. Danube islands were sold in 1262 and before early 1305, most probably in 1304 (Kiss, 2019a): according to both the OWDA and documentary evidence (see e.g. Rohr, 2007; Glaser, 2013), both years were particularly dry not only in the Carpathian Basin, but also in Western and West-Central Europe. Moreover, extreme low water-level conditions of the Danube were directly reported in Lower Austria in 1304 that fits rather well to potential low water level conditions of the Danube that made island areas (temporarily) larger, and increased the chances of the owner to sell the island for a better price.

A further group of frequently-documented events that had a higher likelihood of occurrence in dry (and windy) periods is fires. Although (unintentional) fires can also occur during hard winters and/or other cold and windy periods, and therefore reported major fire events cannot be automatically connected to a dry spell or drought, fire outbreaks have more chance to become particularly extensive and destructive under dry and/or windy than wet conditions. Moreover, during hot (and dry) periods the likelihood for the occurrence of convective events with thunders and lightning – often responsible for the start of major fire events – is also much higher (e.g. 1506: Eger; see Kiss, 2017). Significant years with many fires were, for example, reported in 1473; but charters also refer to fires in a number of cases in the 14th, 15th and early 16th centuries.

For example, fires were reported prior to 1305, May 1314, in 1317, before 1324, in 1332, 1354 and 1400 – in these years dry or very dry conditions were reconstructed by the OWDA (Cook et al., 2015). However, other years with known major fire events, for example 1338, 1342, 1350, 1351 or 1356, were not marked as dry in the OWDA catalogue (data: Kiss, 2016). Nevertheless, as most of the fires can be only dated prior to its mention to an unknown time, this dating uncertainty may limit the possibilities for a more accurate comparison. More clear relationships between dry conditions and fires were documented in the late 15th-early 16th centuries when almost all reported great fires occurred in years when dry or very dry conditions were suggested by the OWDA. For example, dry or very dry (spring-)summer periods coincided with the years with major town/settlement fires in 1482, 1489, 1500, 1506, 1512, 1515, 1518 or 1525; even if, for example, the town fires of 1518 and 1524 mostly do not 'fit' this series with its average or wetter conditions (data: Kiss, 2019b).

Another important group of indirect indicators in the late-medieval period is the major local-regional Ottoman Turkish raids (not the military campaigns of the emperor) in Hungary and Slavonia. Prolonged dry periods with low water levels of major rivers, dry summer-early autumn periods and/or hard winters with steady frosts (with or without snow) and firmly frozen rivers greatly increased the likelihood of swift Turkish raids. Thus, even if, similar to fires, this indicator does not necessarily refer to dry conditions, dry conditions – just like in the 1517 case – made favourable conditions for the Turkish troops nearby the country borders for a devastating attack in (Northern) Slavonia or Southern Hungary. Years with swift devastating Turkish attacks, also mentioned in documentary evidence as dry were, for example, 1473, 1474 and 1479. Moreover, the OWDA suggests notably dry conditions or even drought in other years with known major Turkish raids, for example, in 1418 (see Bánlaky, 1928; Cook et al., 2015).

Food shortages and the mention of dearth or famine – as well as prolonged problems among traditionally pastoral communities – generally refer back to (multiannual) harvest problems, often, but not exclusively induced by drought. As for the pastoral communities, the problems of the Morlachs in Dalmatia were mentioned in relation with the great drought in the early 1360s and the grave poverty of Cumans and Iasonians in the early/mid-1470s and 1410s (see Kiss and Nikolić, 2015; Kiss 2017, and the present paper). Some of the reported significant food shortages such as, for example, 1312 (Kiss et al., 2016), coincided with very dry conditions in the OWDA for 1312 and also with Central European documentary evidence for 1311 and 1312 (Rohr, 2007; Cook et al., 2015; Kiss et al., 2016). Another case that refers to countrywide problems is 1381: in this year there was significant dearth (see Kiss et al., 2016). As there was also plague epidemic in the country, dearth might be also due to that; however, as based on the OWDA this year was very dry in the Carpathian Basin, another possibility is that, due to drought, the harvest was bad in this year. A further, thought-provoking example is the report from Csicser (Čičarovce-Sk; see Fig. 1) in the north-eastern part of the Great Hungarian Plain about the grave poverty, starvation and even death of serfs in 1500; another year suggested as rather dry by the OWDA (Cook et al., 2015).

As we could see it on the example of 1517, apart from food shortages, large-scale shortage or lack of animal fodder could as well have disastrous consequences, in the form of mass loss of animals – especially when a hard winter followed the bad hay harvest caused by drought. On a local scale, probably similar problems were recorded in Temes County in May 1511, when during the hard winter of 1511 a significant shortage or lack of hay developed, and some serfs and landowners started illegally or even forcedly take their neighbours fodder (HNA DL 37883). As both (spring-)summer periods of 1509 and 1510 were rather dry according

to the OWDA, apart from the hard winter in Central Europe (see e.g. Brázdil et al., 2013; Glaser, 2013) that could be – even alone, in itself – responsible for the critical shortage of hay, previous weak hay harvest results, caused by drought, might have also been a contributing factor to the considerable shortage of fodder.

During prolonged food-supply problems there is a higher likelihood of social unrest as happened, for example, during the climatic anomaly of the early Spörer solar activity minimum (see Camenisch et al., 2016). It is also interesting that the great Peasant Revolt of 1514 (started in Transylvania already in 1513) was, according to the OWDA (Cook et al., 2015) and also to Central European documentary evidence for 1513 and 1514 (e.g. Rohr, 2007; Glaser, 2013; Brázdil et al., 2013), preceded by a rather severe multiannual (spring-)summer drought period (see also Kiss, 2019b).

Additionally, sometimes there are also interesting coincidences that might not have a key influence on the flow of events but probably still had some additional negative effects that made a crisis situation even graver. Although we found no direct mention of a drought in documentary evidence, an interesting example is the case of Trau/Trogir in 1420. As part of the (multiannual) Dalmatian war, in this year the town was besieged and cut off from all supply (see e.g. Bánlaky, 1928), which caused great famine and lack of water in the town, and finally forced town citizens to give up resistance and accept Venice as their natural lord (Fejér, 1844a). Coincidently, based on the OWDA, the Dalmatian coastline and Trogir in specific had to endure drought in these years. In fact, the drought was the most severe in 1420 (Cook et al., 2015), which circumstance might have made water (and food) supply for Dalmatian towns, and also for Trogir, even more difficult than in average or wet periods. The year 1420 was outstanding warm in West and Central Europe also based on documentary evidence (see e.g. Brázdil and Kotyza, 1995).

Hunger in extensive areas of Dalmatia was similarly recorded in 1413, referring to 1412 (Mályusz, 1994) – based on the OWDA a year with rather dry conditions in the Croatian kingdoms (including Dalmatia) and most of Hungary. However, similar to 1420, war with Venice (and potentially also pestilence) might also have negative impacts in these areas, though in this year the lands of Dalmatia were less directly affected by the war than in 1420 (Bánlaky, 1928). Even further back in time, a potentially similar case was recorded in 1304, when great poverty was described in "Slavonia" (referring to any of the Croatian kingdoms) – one of the reasons of these grave problems might be political uncertainties (Kiss, 2016). Nonetheless, as suggested by the OWDA and also documentary evidence from other parts of Central and Western Europe (e.g. Alexandre, 1987; Brázdil and Kotyza, 1995) a possible reason could also be prolonged drought.

Another, rather indirect and uncertain but still thought-provoking case, this time in Hungary, is 1525. According to the Sperfogel chronicle, after many years of regular tax increase and the repeated devaluation of the currency, with reference to the (otherwise real) danger of a major Turkish attack, in 1525 the king decided to apply again the dangerous tool of money devaluation, which led the country into great price increase and the lack of even basic goods purchased abroad (Wagner, 1774). And although no any mention of a drought is known from contemporary evidence, based on the OWDA there was significant drought in 1525 that could increase the negative consequences of the money devaluation and the possibly multiannual impacts of plague epidemics, hitting the country in 1522-1524 (see Kiss, 2019b).

As we could see in the present paper on the example of the 1370s, in certain cases the conditions of watermills, ditches (stagnant water bodies, fishponds/fisheries, meadows) might be applied as indirect indicators of a dry spell. Additionally, further potential, indirect indicators might be worth to test in future. In England, for example, even the mention of dried up trees in contemporary administrative sources in certain years might be an indicator of drought (see e.g. Pribyl, 2017).

OWDA droughts – with no documentary evidence?

Although regarding many of the years, highlighted by the tree-ring based OWDA hydroclimate reconstruction, at least indirect evidence is available, some markedly great drought years in the OWDA reconstruction up to now has no any connected, direct or indirect, late medieval documentation in the Carpathian Basin.

Based on the OWDA, in the Carpathian Basin the cumulative (extrapolated) PDSI values were under (or around) -1 in 1300, 1303, 1306, 1311, 1314, (1317), 1320, 1322-1324, 1326, (1328), 1334, 1335, 1354, 1355, 1357, 1358, 1365, (1367), 1377, 1381, 1385 and 1403-1406, 1412, 1417, 1419, 1422, 1423, 1427, 1431, 1433, 1443, 1444, 1500, 1503, 1506, 1507, 1513, 1514, 1518 in late medieval times. This value was (around or) under -2 in (1312), (1323), 1325, 1332, 1360, (1362), 1384, 1420, 1421, 1426, 1439, 1440, 1473, 1479, 1480, 1483, 1484, 1504, 1512, 1516, 1519, (1520), 1525. In two cases, in 1333 and 1517, the PDSI value was under -3, and in one case in late medieval times this index value was under -5, in 1361 (data: Tree Ring Drought Atlas Portal).

However, we have to add that these values refer to the entire Carpathian Basin, and within this large region, there could be great regional differences in drought intensity within the same year. For example, in case of a great drought in the eastern and central parts of the Carpathian Basin, it was rather possible that the drought did not affect the western parts of the Basin, and in this case the average PDSI index might not show any extreme on the level of the entire Carpathian Basin, even if clearly there was a significant drought in that year. A potential example for such a case is 1507 (see Kiss, 2019c).

Out of the years with under -3 PDSI values, we have not yet found any documentary-based reference for 1333, but sources do refer to 1361 and 1517 (Kiss, 2017; and in the present paper). Direct or indirect evidence is also available for the years with PDSI values under -2, in 1360, 1362, 1420, 1426, 1439-1440, 1473, 1479-1480, and probably for 1483 and 1504, but some kind of (even if very indirect) information can as well be connected to most of the years with PDSI values under -1 (see examples in the present paper), even if the causal relationship in most cases cannot be proved with certainty.

CONCLUSIONS

In the present paper potential dry spells, mainly available in indirect evidence, as well as uncertain and contradictory cases are discussed and compared to the tree-ring based (spring-)summer hydroclimate reconstruction of the OWDA. Direct and indirect evidence refers to dry spells or even a potential drought in the 1370s, while a contradictory, mixed dry and probably very rainy and then again dry periods are discussed in the 1410s, and a potential multiannual dry spell or drought in the 1420s. Rather clearly drought-related information comes from the year of the Reformation, 1517, with indirect reference to 1516.

Furthermore, groups of (potential) indirect evidence, presented in medieval legal-administrative (mainly charter) documentation were defined. The presence and more frequent occurrence of problem groups in certain years or periods may help us to identify more dry spells or droughts without direct reference in contemporary documentation.

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