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USE OF LATE 18TH AND EARLY 19TH CENTURY CADASTRAL DATA TO ESTIMATE PAST FOREST COVER CHANGE – A CASE STUDY OF ZAWOJA VILLAGE

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Abstract: Previous studies concerning forest cover changes in the Polish Carpathians did not formerly extend further than the mid-19th century, because of the lack of detailed cartographic materials. Earlier forest changes, especially their magnitude but sometimes even their direction (deforestation, stabilisation or afforestation) are poorly investigated. This paper shows how to extend a temporal sequence of forest cover data for Zawoja village in the Polish Carpathians using non-cartographic data from the late 18th and early 19th centuries. We used non-cartographic data from the first Austrian cadastral system, the so-called Josephinian cadastre, carried out in the 1780s, and its revision done in 1819–1820. These data were compared with the stable cadastre and its two revisions (1844–1898) and mostly later cartographic materials (1861–2014). Thematic coherence of cadastral and cartographic data, conformity of Zawoja village boundaries in the analysed period, as well as errors of the earliest cadastral measurements were investigated. The data acquired in the 1780s and 1819–1820 enabled the estimation of the productive and non-productive forest area as well as the area of pastures and meadows partly covered with forest. Though possible measurement errors could add up to 7% of the total village area, the data clearly document the end of the deforestation phase ongoing in Zawoja until the first half of the 19th century, and later relative stabilisation of forest cover during the second half of that century. Data from the late 18th and early 19th centuries indicate a change trend opposite to the later, frequently described stabilisation of forest cover and progressive afforestation. Using the unpublished data extracted from cartographic materials, we also show this latter part of long term forest cover changes, thereby presenting an example of forest transition in the Polish Carpathians.

Keywords: forest cover change, land use, data integration, Josephinian cadastre, stable cadastre, the Carpathians

Introduction

Lack of detailed cartographic materials for the Carpathians older than the Austrian second military survey map meant that most previous studies concerning forest cover changes did not extend further than the mid-19th century. Meta-analysis of different case studies from the Polish Carpathians (Kozak 2010) and the whole Carpathians (Munteanu *et al.* 2014) did not give us a clear answer concerning the change direction of forest cover over the 19th century (increase or decrease) and the timing of forest transition. Forest transition theory depicts a reversal of forest cover trends – from forest decrease to increase, following typically major changes in human activities (e.g., industrialisation and decline of the economic importance of agriculture; Mather 1992). Did this switch occur in the Polish Carpathians only during the Interwar period or earlier, in the mid-19th century? Shortages of reliable spatial data from the period prior to the mid-19th century do not allow, however, to pinpoint the moment of this reversal in the temporal sequence. A relatively early (1770s) topographic map of the area is considered to be inaccurate and not reliable in the context of land cover analysis. Therefore, to extend the temporal sequence of forest cover data, we looked for non-cartographic measurement records available from the former Austrian cadastral surveys carried out in the 1780s (so-called Josephinian cadastre), and from its revision done in 1819–1820. Except by Augustyn (2009, 2012) these data have not been used in combination with newer cartographic sources as they pose several difficulties in analysis. This paper presents an approach to use the late 18th and early 19th century cadastral data for long term forest change reconstruction. We discuss thematic coherence of cadastral and later cartographic data as well as errors of the earliest cadastral measurements. All data were collected as summarised statistics extracted for the entire village (cadastral commune), so the conformity of Zawoja village boundaries in the whole analysed period is also discussed.

Study area

The village of Zawoja (100 km^2) is located at the foot of the Babia Góra massif (1725 m a.s.l.) in the upper Skawica river basin. Zawoja was founded in the first half of the 17th century (first mentioned in 1646), as one of numerous shepherd villages (villages established 'ex cruda radice') emerging in the last large phase of settlement spread in the Polish Carpathians (Baranowski 1916). Until the second half of the 18th century, Zawoja and the adjacent, slightly older, Skawica (founded before 1593) were treated as one village (cf. Troll 2015). The whole land belonged to royal domains (the district of Lanckorona) which, after the first partition of

Poland in 1772, became part of the new Austrian province of Galicia. As the former royal domains, this land was taken over by the Austrian Government, forming a part of the 'cameral estate' as the Maków dominion.[1] The definitive separation of Zawoja and Skawica villages took place most likely with establishing the Josephinian cadastre in the 1780s (Troll 2015). In 1839, the cameral estate of Maków was sold to Count Filip Saint-Genois d'Anneaucourt, who developed a smelting industry, intensifying the exploitation of local forests (cf. Kawecki 1939). In 1878, Zawoja became part of the estates belonging to the Habsburgs of Żywiec (Zabielski *et al.* 1969). In 1924, the Habsburgs transferred Zawoja forests to the Polish Academy of Arts and Sciences (PAU – Polska Akademia Umiejętności), which owned them until 1939 (*Lasy dóbr…* 1929). In 1933, in the Babia Góra forest of PAU, a nature reserve, called a national park was created (Szafer 1963). Babia Góra National Park became officially established in 1954 and was enlarged in 1997. Currently, it encompasses about 33.5% of the Zawoja forests.

In the historical literature dedicated to local forests (*Opis dóbr…* 1905; *Lasy dóbr…* 1929; Kawecki 1939; Dzięciołowski 1963; Zabielski *et al.* 1969) data about Zawoja's forest area in the 18th and 19th centuries are missing, except for some information about forest exploitation (cf. Kawecki 1939). Forest cover changes in Zawoja commune (including Skawica village) between 1935 and 1999, were studied by Woś (2005) showing gradual afforestation, resulting in a 16% increase in forest cover.

Source materials

Sources of data on the area of forests

Information on forest cover at the end of the 18th century and during the 19th century comes from subsequent surveys of the former Austrian land cadastre:
– the Josephinian cadastre of 1787–1788;
– the revision (rectification) of the Josephinian cadastre of 1819–1820;
– the stable cadastre of 1844–1845;
– the revisions of the stable cadastre of 1858 and 1898;
and from the Austrian second military survey map (2MS map) from the years 1861–1862, the outcome of the revision of the stable cadastre.

Additional information, which was used to show the forest cover changes occurring in the 20th and 21st centuries, came from cartographic materials and digital databases:

[1] The dominion constituted the administrative unit of the lowest level.

– Polish topographic map of the Military Geographical Institute (WIG) in the scale of 1: 100 000, from the beginning of the 1930s;
– topographic map of the Surveyor General of Poland (GGK), in the scale of 1: 25 000, from the years 1978–1979;
– national Polish topographic data (Baza Danych Obiektów Topograficznych, BDOT10k), updated with other data.

Forest cover information was obtained from above mentioned cartographic materials within the framework of separate studies discussed in detail elsewhere (Kaim *et al.* 2014, 2016; Ostafin, Dobosz 2016; Ostafin *et al.* 2016). Data extracted from these datasets for Zawoja village were not previously presented.

Josephinian cadastre (Josephinischer Kataster) survey results, stored at the Central State Historical Archives of Ukraine in Lviv (TsDIAL), are reported in numerous documents, known in Polish and Ukrainian literature as Metryka Józefińska (e.g. Styś 1932). We used four different documents from the preserved part of Zawoja cadastral documentation. A so-called 'boundary description' (*Grentz-Beschreibung*) is the protocol detailing communal boundaries of Zawoja (discussed below). The general summary record (*Summarium*) contains aggregated values of taxable land areas, for land use categories highlighted in the Josephinian cadastre, and for two types of landownership: *dominion* and *rustic*. A document with a basic description of survey results (*Fassions-Grundsätze*; pol. *Fundamenta*) was the source of descriptive information on the occurrence of forests on meadow and pasture lands. The book of land income or 'measurement book' (*Grundertragsmatrikel*) made it possible to determine which areas were measured by a specialist (*geometrician*), and which by peasants. The results of measurements carried out by *geometricians* and by peasants were projected onto a plane (*Instruktion*… 1907),[2] which is important from the point of view of data comparability.

During the revision of the Josephinian cadastre, carried out within the framework of the provisional land tax (*Grundsteuerprovisorium*) in 1819–1820, new measurements of parcels were performed only when their boundaries changed. The only preserved piece of documentation from this revision is a book of land income for Zawoja, stored in TsDIAL. This document provided us with data on forest areas in 1819–1820. As the revision was carried out by the same land authorities and in the same cadastral boundaries as the Josephinian cadastre (*Einführung*… 1819), land use categories, including forests, were aggregated for the same area (within Zawoja's boundaries as defined in 1787).

The survey of the stable cadastre (*Stabile Kataster, Franziszeischer Kataster*) for Galicia was carried out in Zawoja in 1844–1845. Cadastral documentation for Zawoja

[2] We were unable to locate the original measurement instruction for the representatives of the commune: *Belehrung, wie die Ausmessung der Gründe von den Gemeinden praktisch zu vollziehen sey sein.*

is fragmented in several institutions and is not complete – data for 7325 out of 23 655 land parcels and 2 out of 46 sections of the cadastral map are missing, so the source of the data on forests recorded during this survey was a summary record (*Ausweis über die Benützung des Bodens für die Gemeinde Zawoja*). The first revision of the stable cadastre was carried out in 1858, and cumulative results were published in two documents (*Skorowidz*… 1868; *Przewodnik*… 1872). The summary results of the later revision of 1898 were found among the files of the first stable cadastre documentation (1844–1845).

Sources of information about the Zawoja boundaries

Contemporary boundaries of the village of Zawoja were taken from the digital National Register of Boundaries (PRG; *Państwowy*… 2015). Boundaries delimited in the stable cadastre of Zawoja were vectorised from the 2MS map. To reconstruct the village boundary in the 1780s, we used the 'boundary description' document from the Josephinian cadastre, containing a detailed and accurate (compared with similar documents for other cadastral communes) verbal description of the Zawoja boundary course.

Methods

In order to compare all data included in the temporal sequence, a common spatial unit, defined by the Zawoja village boundary, was used. In the case of the first cadastral dataset (1787–1788), only the main land use categories, such as *forest* – divided into productive and non-productive – *pastures and shrubs*, *meadows*, *orchards* and *arable land* were already summarised for the whole cadastral commune. To extract areas of *pastures and shrubs* and *meadows* which were covered with forest patches, we had to study the cadastral documentation. From the preserved documentation of the second cadastral system (1819–1820), we collected summarised data divided only into three main land use categories: *forest*, *meadows* (including pastures, shrubs and orchards) and *arable land*. In the cases of the stable cadastre and its later revisions, also summarized but more detailed data were available. For 1844–1845 we could choose land use categories similar as in the first dataset, however *forests* were divided into high coniferous, high mixed and low forest – not into productive and non-productive. Additional categories of *non-productive land* and *built-up areas* were also chosen as categories correspondent to areas non-measured during surveys in 1780s and 1819–1820. For two revisions of the stable cadastre (1858 and 1898), similar to that of

1819–1820, we could not extract areas of the above mentioned forest categories nor areas of pastures and meadows covered with trees.

Later forest cover data were extracted from cartographic datasets (2 MS, WIG, GGK, BDOT10k), which were already integrated in the PL-1992 coordinate reference system (for details see: Kaim *et al.* 2014, Ostafin, Dobosz 2016). In the case of all cartographic datasets, we could use only one forest category, as forest patches (trees) situated on pastures and meadows are not distinguished.

Thematic coherence of the cadastral data with respect to land use

The *forest* category in the cadastral records of 1787–1788 and 1819–1820 includes also forests situated in the upper timberline zone and subalpine shrubs (*Krummholz vegetation*) treated as non-productive forest, as well as natural alpine meadows on the summit of Babia Góra,[3] thus leading to a slight overestimation of forest area (Tab. 1). On the other hand, some forested areas were probably reported as pastures (or even as meadows) or were omitted as wasteland. Therefore, instead of providing

Table 1. The thematic coherence of data on forest cover, acquired during former Austrian cadastral and military surveys

Dataset	Feature	Forest definition	Notes
Josephinian cadastre (1780s) and its revision (1819–1820)	Forest parcel, pasture parcel covered with forest patches, meadow parcel covered with forest patches	Land use or land cover	Patches of subalpine forest used as pasture might be evidenced as *pasture and shrubs* Non-productive forest might be evidenced as *forest, pasture and shrubs* or may not be measured and evidenced *Krummholz* may be evidenced as non-productive forest or as *pasture and shrubs*
Stable cadastre (1840s–1890s)	Forest parcel, pasture parcel covered with trees, meadow parcel covered with trees	Land use	Patches of subalpine forest used as pasture may be evidenced as *pasture* (or *pasture with trees*)
2MS map (1860s)	Area of dissolved parcels from the stable cadastre	Land use	Land use from stable cadastre documentation, revised in field

[3] This assumption is confirmed by a statement in the document with a basic description of survey results (*Fundamenta*): [*Babia Góra*] *with forest is measured* and by the description of wastelands included in the same document, which does not mention any wasteland at the peak of Babia Góra. No *meadows* or *pastures and shrubs* were evidenced there either. Our interpretation of the cadastral documentation could be verified with a forest map prepared at that time, yet, unfortunately, we were unable to find this document in the archives.

one forest area value, we use value ranges, in which the minimum value relates only to the productive forests and the maximum one to the productive and non-productive forests as well as pastures and grasslands with forests.

Similarly, in the case of the stable cadastre and its revisions (1844–1898), the *forest* category may be underestimated, assuming that subalpine forests used as pastures were evidenced as *pastures with trees*. We estimated the maximum forest cover adding *pastures with trees* to the forest category.

Conformity of the past and present village boundaries

In the case of area-aggregated cadastral data, any changes in the historical boundaries of Zawoja may influence the comparability of forest cover statistics. Our comparison of the area of Zawoja cadastral commune recorded in the summaries of the stable cadastre (1845) and its revision (1898) with the area calculated according to the *2* MS map, shows that the *2* MS map is a faithful representation of the boundaries used in the stable cadastre and its revision (areal differences do not exceed 0.15%). Comparison between the *2* MS boundary and the contemporary one, also showed their almost exact coincidence (areal difference is negligible, approximately 0.03%).

To identify the boundary course in 1787 we tracked locations of the boundary mounds reported in the boundary protocol and compared distances between subsequent mounds (expressed in Vienna fathoms, 0.527 m) to distances measured along the contemporary boundary. 92% of the total length of the contemporary boundary (44 km) coincided with the boundary defined in 1787, with the difference between their total lengths equal to 0.7%. For two sections we were unable to identify the course of the Josephinian boundary; therefore we estimated only the areal difference related to boundary changes after 1820. Our estimates showed that the area of Zawoja cadastral commune increased then by approximately 70 ha.

Estimation of measurement errors and areal data adjustment

A critical issue in our study is the discrepancy between the area measured during the Josephinian survey and its revision in 1819–1820, and the whole area of the cadastral commune. This discrepancy results from the omission of the tax-free non-measured land (built-up areas, streams, mill streams, roads, livestock trails, balks and other wasteland) and from measurement errors. According to Styś (1932, 1934), errors in the Josephinian measurements resulted in the underestimation of the measured area in a village. Hence, we assumed that some area was lost during the measurement. To estimate the size of 'lost area', we adopted a minimum size of non-measured land for 1819–1820 as equal to the area of corresponding

categories (built-up and wasteland) in 1844–1845, as we do not dispose of any other approximation of non-measured land in that time. Then we backdated this value to 1787–1788, using the increase in the area of non-measured land between 1787 and 1820, which is known.

Such estimation gives the maximum 'lost area', which is a difference between the sum of all land use categories, including the adopted size of non-measured land, and the total village area: in case of the Josephinian survey and its revision, it amounts to 670 ha, that is less than 7% of the village area. Then, all land use class areas were adjusted proportionally for the 'lost area', regardless who carried out the measurement of a land use class – peasants or a *geometrician*. In theory, all land use class area could be measured without any errors – it means that no area was lost – but in such a case the whole difference between total village area and measured area must relate to non-measured land. As we cannot exclude such a case, we use value ranges of non-measured land and the respective value ranges of the 'lost area' in 1787–1788 and 1819–1820.

Finally, we corrected the estimates accounting for the 70 ha difference between the present and the past village area. According to the verbal 'boundary description' we found that this area was almost exclusively forested; therefore, to allow a comparison of the aggregated data from the years 1787–1788 and 1819–1820 with the remaining part of the temporal sequence, we added 70 ha to the adjusted values of forest area.

Results

In 1788, according to the raw and uncorrected data, the *forest* category constitutes 74% of the total measured area (Tab. 2). Part of these forests (3.1% of the total measured area) was recognised as non-productive, and classified as *Swampland and deserted [wild], waste and empty places* (*Morästen und wüsten, unnutzbahren leeren Strecken*). Forests growing on meadows and pasture (*alder forests, beech forests, fir forests and spruce forests*) covered 1.2% of the total measured area.

The adjusted forest proportion related to the contemporary village area ranged from 68.7% to 73.6%, and, excluding non-productive forest, from 65.9% to 70.6%. The range width accounted for the estimated uncertainty of the non-measured land area is 0.8%–7.5%.

In 1820, according to the source data, *forests* accounted for 68.7% of the measured land area (Tab. 3). The cadastral documentation of this revision did not provide a clear reference to any changes of non-productive forests evidenced in 1787–1788 in the Babia Góra massif (their area remained therefore the same, 3.1%). The area of meadows and pastures covered with forests in 1820 is unknown.

Table 2. Land use in Zawoja cadastral commune, according to the records of the Josephinian cadastre documentation (1787–1788) – the raw uncorrected and the adjusted data

Categories of land in the Josephinian cadastre	Area in 1788 – source data		Area in 1788 – data adjusted for the boundaries of 1787		Area in 1788 – data adjusted for contemporary boundaries	
	ha	%	ha	%	ha	%
Arable land	1767.20	19.1	1767–1895	17.7–18.9	1767–1895	17.5–18.8
Meadows (with forests)	146.41 (< 20.18)	1.6 (< 0.2)	146–157 (20–22)	1.5–1.6 (0.2)	146–157 (20–22)	1.6 (0.2)
Gardens (orchards)	12.14	0.1	12-13	0.1	12-13	0.1
Pastures and shrubs (with forests)	477.79 (< 95.29)	5.2 (< 1.0)	478–512 (95–102)	4.8–5.1 (1.0)	478–512 (95–102)	4.7–5.1 (0.9-1.0)
Forests (*non-productive forests*)	6850.89 (285.43)	74.0 (3.1)	6851–7346 (285-306)	68.5–73.4 (2.9-3.1)	6921–7416 (285-306)	68.7–73.6 (2.8-3.0)
Range of non-measured lands – wasteland and built-up areas	no data	no data	81–749	0.8–7.5	81–749	0.8–7.4
Total	9254.43	100.0	10004	100.0	10074	100.0

Source: Based on: TsDIAL of Ukraine, *Iosyfinska metryka*, fond 19, opys VIII, sprava 110 (2).

The total measured area decreased by 77 ha as compared to 1788, which means an increase in the non-measured area (1.6%–7.7%). Contrary to what may be implied from the comparison of the forest cover loss and increase in agricultural land between 1788 and 1820 (Tab. 3), the increase in the non-measured area concerns the agricultural lands of 1788 damaged by floods.[4]

The adjusted forest proportion in relation to the contemporary village area ranged from 63.3% to 67.8%, and excluding non-productive forests, from 60.5% to 64.8%. Maximum values are probably underestimated due to the lack of information on the area of forested pastures and meadows.

In 1845, the *forests* category amounted to 48.6% (Tab. 4), consisting almost exclusively of coniferous high forests (48.5% of the total village area; mixed high forests and low forests constituting the remaining 0.1%). Subalpine and alpine parts of the Babia Góra massif were not treated as *forest* in 1845. This area was divided into two large plots: one was reported as rocks (subalpine and partly alpine zone)

[4] Mainly in 1813; such a note appears many times in the revised book of land income.

Table 3. Land use in Zawoja cadastral commune, according to the revision of the Josephinian cadastre (1819–1820) – source data, adjusted data and their changes within the period of 1788–1820

Categories of land in the Josephinian cadastre	Area in 1820 – source data		Area in 1820 – data adjusted for the boundaries of 1788-1819		Area in 1820 – data adjusted for contemporary boundaries		The difference between 1820–1788 for the data adjusted for contemporary boundaries	
	ha	%	ha	%	ha	%	ha	% of 1788
Arable land	2209.47	24.1	2209–2370	22.1–23.7	2209–2370	21.9–23.5	442–476	25.0–25.1
Meadows, *gardens, pastures and shrubs*	663.60	7.2	664–712	6.6–7.1	664–712	6.6–7.1	27–30	4.3
Forests (*non-productive forests*)	6304.30 (*285.43?*)	68.7 (*3.1?*)	6304–6763 (*300–306?*)	63.0–67.6 (*2.8–3.0?*)	6374–6833 (300–*306?*)	63.3–67.8 (*2.8–3.0?*)	(–582) – (–547)	–7.9
Range of non-measured lands – wasteland and built--up areas	No data	No data	*158-826*	*1.6-7.7*	*158-826*	*8.2*	*n/a*	*n/a*
Total	9177.37	100.0	10004	100.0	10074	100.0	*n/a*	*n/a*

Source: Based on: TsDIAL of Ukraine, *Frantsyskanska metryka*, fond 20, opys VIII, sprava 163.

Table 4. Land use in Zawoja cadastral commune according to the stable cadastre (1844–1845) and its two revisions (1858, 1898) as well as their changes within the period 1845–1898

Land use categories in the stable cadastre	Area in 1845		Area in 1858		Area in 1898		Difference between 1898 and 1845	
	ha	%	ha	%	ha	%	ha	% of 1845
Arable land	3184.51	31.6	3183.44	31.5	3112.57	30.8	–71.94	–2.3
Meadows (including *grasslands with trees*)	265.43 (13.49)	2.6 (0.1)	222.70	2.2	239.27	2.4	–26.16	–9.9
Gardens (orchards)	8.00	0.1			12.53	0.1	4.53	56.6
Pasture (including *pasture with trees*)	1364.58 (468.59)	13.5 (4.6)	1388.01	13.8	1323.70	13.1	–40.88	-3.0
Forests (including conifer high forest, mixed high forest, low forest)	4901.19 (4898.97 1.89 0.33)	48.6 (48.5 <0.1 <0.1)	4932.84	48.9	5060.05	50.1	158.86	3.2
Built-up areas	17.99	0.2	*364.87**	*3.8**	20.14	0.2	2.15	12.0
Wasteland (incl. *rocks*)	350.18 (192.46)	3.5 (1.9)			330.21	3.3	–19.97	–5.7
Total (area of the cadastral commune)	10091.87	100.0	*10091.87**	*100.0*	10091.54	100.0	–0.33	<0.1

*As the total surface of the cadastral commune in 1858 was unknown, the surface for 1845 was used to calculate the total area of wasteland and built-up areas.

Source: Based on: The National Archives in Kraków, Spytkowice Division, *Kataster galicyjski*, Kat. Gal. II, Op 3478, Kat. Gal. II, Op 4848; *Skorowidz…* 1868, *Przewodnik…* 1872.

and the other as a *pasture with trees* (partly in subalpine and upper timberline zones). The categories *pastures with trees* and the less frequent *meadows with trees* covered 4.7% of the village area. Cadastral measurements within the stable cadastre and its revisions covered the entire surface of Zawoja village, including wasteland and built-up areas which constituted 3.7% of the total area.

According to the stable cadastre revision of 1858, *forests* constituted 48.9% of the area, however, data on the area of pastures and meadows with trees are missing. This revision is the closest one to the publication of the *2* MS map of Galicia (1861–1862). Forest area based on the map information equalled 48.3% of the total village area (Fig. 1), that is only 0.6% less than the cadastral estimate. With the next revision in 1898, *forests* constituted 50.2% of the total area; again, the share of pastures and meadows with trees was not documented.

Later cartographic data showed a steady increase in the proportion of forest area: from 52.3% in the 1930s, 62.6% in 1978–1979, to 70.5% in 2013 (Fig. 1).

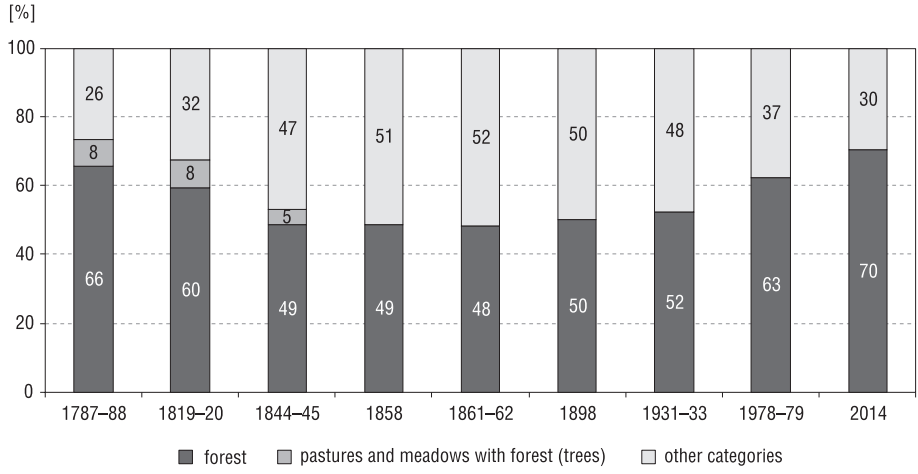

Fig. 1. Forest cover changes in Zawoja village (1780s – 2010s). Values for the first two time periods adjusted for measurement errors (see Tab. *2* and 3)

Discussion

The thematic coherence of cadastral data

For the current investigation the main advantage of the cadastral data from the first two cadastral systems (1787–1788, 1819–1820) is the distinction between productive and non-productive forests, and additional information about forest patches situated on pastures and meadows. The disadvantage is their low accuracy in general and the lack of knowledge about the magnitude of geometric and thematic measurement errors in particular. For these reasons, we used ranges of forest area, in which the minimum value referred to the area of forest in the strict sense, and the maximum value accounted for forested pastures or meadows. The latter seems important as animal grazing in forests was common in the Polish Carpathians until the regulation of forest and pasture servitudes in the second half of the 19th century. Abundance of forests in the lower, more easily accessible parts of the Maków dominion in the mid-19th century (Kawecki 1939), could result in using such less accessible forests situated in Zawoja as pastures.

In these first two cadastral systems the highest subalpine forests and *Krummholz* (mostly dwarf pine shrubs) evidenced in Zawoja, were considered as non-productive forests. However, in other villages, not only the pastoral ones, the same land cover types could have been included in the pasture category as the cadastral land surveys could be carried out differently in various dominions, though according to the cadastral instruction all non-productive forests should be evidenced as pastures (*Informacya*... 1785).[5] Some forest areas could also be treated as wasteland and therefore excluded as in Wołosate village (Bieszczady Mts.), where up to 3% of the total area of forests was not measured in 1787–1788 (calculation based on: Augustyn 2009).

Some underestimation of the *forest* category was also possible in the stable cadastre, in the case of large mountain pastures, common in many villages situated in the former Polish Eastern Carpathians. Subalpine forests used for animal grazing could have been evidenced as pastures and not separated from the open land (Troll 2013). The case of Zawoja shows different thematic incoherence between the stable cadastre and earlier cadastral systems, as subalpine and alpine parts of the Babia Góra massif were treated in the Josephinian cadastre as non-productive forest. Such a small – in the sense of its area – overestimation of forest cover, was later eliminated in the stable cadastre, where those parts were evidenced partly as *pasture with trees* and as *rocks*.

[5] According to the statement, the revenue from such non-productive forests used as pastures should be registered as the revenue from forests. Such cases have not been found in the cadastral documentation for Zawoja, perhaps because such forests were taxed higher than pastures.

Based on these complex relations between various land use categories in subsequent cadastral surveys, it is clear that adding pasture with trees to the forest category (as we did to assess maximum forest area, see Tab. 4) leads undoubtedly to overestimation of the forest area. The uncertainties in forest cover change estimates for the whole province of Galicia, emerging from the comparison of the stable cadastre and the earlier data were already indicated (cf. Szczerbowski 1907). However, this emphasised that in the light of the stable cadastre an apparent increase in forest cover occurred, because forests registered formerly as parts of the pastures were separated later in the stable cadastre. The case of Zawoja illustrates the opposite effects of thematic incoherence, but in our opinion such incoherence may be specific for villages possessing small subalpine areas, so its influence on overall statistics, e.g. for the entire Polish Carpathians, is probably not very high.

Measurement errors in the early cadastral surveys

Estimating measurement errors in cadastral surveys of 1787–1788 and 1819–1820 is a key issue for data comparability. The accuracy of these measurements could vary among estates, and was often poor – especially if done by local peasants (Łoziński 1907). Styś (1932) showed, for the Josephinian survey and its revision in 20 villages, underestimation by 8–12% of the measured area as compared to the results of the stable cadastre. Similarly, assessments of the quality of the Josephinian cadastre for the whole of Galicia showed that approximately 10% of the total area (including wasteland) was missing (cf. Bochenek 1883). Not only measurements carried out by peasants contributed to errors: in the Wołosate village the area of the estate forest measured by a *geometrician* was underestimated by almost 10.5% in 1787–1788 and 8% in 1819–1820 (based on data from Augustyn 2009).

According to our estimates, the maximum surface area lost in Zawoja in the Josephinian survey and its revision was respectively 6.7% and 6.1%, in relation to the area of the cadastral commune at the time. These values testify to more accurate measurements in Zawoja than those received by Styś (1932) for villages located further east. For simple distance measurements along the boundary of the village, carried out by the peasants in 1780s, such accuracy was even higher as was proved by results of the comparison to the contemporary boundary.

Forest cover change

The analysis of the temporal sequence of a variety of source materials spanning more than 200 years revealed forest cover changes in Zawoja village. Data from the first three surveys (1787–1788, 1819–1820, 1844–1845) show a clear decrease

in forest cover. Then, forests in Zawoja, almost entirely dominion property, were converted to agricultural land used by the peasants. Changes in agricultural land were observed by Fierich (1950), who analysed the same source materials for 31 villages in Galicia, Styś (1934), who analysed the cadastral data for 20 villages in the central and eastern part of Galicia and by Augustyn (2009), who analysed the data for the village of Wołosate. They all documented the expansion of agricultural lands used by peasants, due to improved management of abandoned areas or division of granges. Quite likely, this process did not substantially affect the area of forests. In contrast, in the Żywiec estate, neighbouring the Maków estate, the forest area stabilised in the second half of the 18th century, because forest management was already an important source of income for landowners in that area (Kawecki 1939; Broda 1956). It seems that the process of village expansion at the expense of the estate forests in the first half of the 19th century was limited mainly to villages, where apart from the significant agricultural pressure (so-called land hunger) there were still large forested areas, which were either not exploited intensively or at least not sufficiently supervised. This was especially true for villages in the less accessible areas of the Polish Carpathians.

From 1845 to 1898 the forest cover in Zawoja was stable, but at the lowest level in the whole temporal sequence (49–50%). Stabilisation of the forest area in the second half of the 19th century was quite a common phenomenon in the Polish Carpathians (Kozak 2010). It was also documented in the summary data for 31 villages analysed by Fierich (1950). The 1% gain in the forest cover between 1845 and 1898 is well below uncertainty levels embedded in the data, yet it could result also from the reforestation of former pastures during regulation of servitudes in the second half of the 19th century. Stabilisation of the forest area between 1844–1845 and 1898 was confirmed also by the 2MS map of Galicia, which was generalised from the stable cadastre, with its revision in the field (Konias 2000). Minor differences between the forest cover from the 2MS map and that reported in the stable cadastre (1845) and its revision (1858) may result from map generalisations and geometric transformations rather than from true forest cover changes.

The slow turn in forest cover trends in Zawoja was visible after 1898, when forest cover increased from 50% to 52% in the 1930s. The difference of 2% should be interpreted with caution, due to the possibility of a slight underestimation of the forest cover in the 1898 data (forest patches within the parcels registered as pastures) and the WIG map generalisation, although the impact of the latter is not as large as one would expect on the basis of the scale of this map (Kaim *et al.* 2014). Increase in forest cover is clearly visible since the 1930s, when forest cover has increased from 52% to 62% and, up to 70% in 2013, similarly to increases documented in numerous studies in other parts of the Carpathians (e.g. Kozak 2010; Munteanu *et al.* 2014).

The presented temporal sequence of forest cover data, covering more than a 220-year period, illustrated the phenomenon of forest transition (Mather 1992) in one of the biggest villages of the Polish Carpathians. The phase of deforestation until 1845 was associated above all with the late formation of the village of Zawoja and its spread to the higher and less accessible parts of the mountains. The phase of stabilisation lasted at least until the end of the 19th century; however, it might well extend until World War II, which preceded the phase of forest cover increase continuing until today. As a result, the contemporary forest cover may be similar to that of the 1780s.

In our study the cadastral data were analysed at the level of the entire spatial unit – a village. Such an approach may be applied only to villages with a known former boundary course, described in the Josephinian 'boundary descriptions', the key document for interpretation of data acquired during the surveys from the 1780s and 1819–1820. However, incompleteness of many cadastral documentation and the low quality of some 'boundary descriptions' are a serious limitation of its application. Another one may be nonconformity of the past and present boundaries.

An alternative approach, based on a full spatial reconstruction of land use (e.g. Augustyn 2009, 2012 for villages Wołosate and Ustrzyki Górne), cannot be applied to Zawoja due to the lack of forest plans in 1787–1788 and 1819–1820, as well as incomplete stable cadastre survey data. Finding the missing documentation could result in this kind of fully spatial reconstruction, and the revision of our estimates of forest cover based on the first two cadastral surveys. However, this approach seems to be much more laborious.

Conclusions

The presented case study for Zawoja village shows that early non-cartographic data can successfully be used to extend the temporal sequence of forest data. Data collected from several former Austrian cadastral and military surveys allowed us to detect forest cover changes since the 1780s and the end of the 19th century. Integrated with later cartographic data they illustrate the forest transition process in Zawoja. The impact of measurement errors for data acquired in the 1780s and 1819–1820 was estimated to be not higher than 7% of the village area. Despite such errors, the high level of detail of the source materials and their relation to the much more accurate stable cadastre permit us to estimate the range of forested area through incorporation of information about forests used as pastures. All cadastral data sources used were kept also for other countries of the former Habsburg Monarchy, making the presented approach suitable for other areas, not only in the Polish Carpathians, as long as such data are available.

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