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Způsoby mapování agrolesnictví, zejména pastvin s dřevinami a lučních sadů

Agroforestry mapping methods, focusing on wood-pastures and orchard meadows

DISERTAČNÍ PRÁCE

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Prohlášení

Prohlašuji, že jsem předloženou disertační práci s názvem „Způsoby mapování agrolesnictví, zejména pastvin s dřevinami a lučních sadů“ vypracoval samostatně a použil pouze prameny uvedené v seznamu literatury.

V Praze dne 29. 3. 2020 Mgr. Michal Forejt

Poděkování

Děkuji za doprovázení doktorským studiem svému školiteli Janu Skalošovi. Dále děkuji svým přátelům a kolegům, kteří se podíleli na zpracování studií, jež tvoří tuto dizertační práci, především Martinu Dolejšovi, Ralfu-Uwemu Syrbemu a Pavlu Raškovi. Především děkuji své manželce Andree za podporu během těch dlouhých let.

Obsah

Úvod

Jak říká název článku švédské geografky Anniky Dahlberg „Kategorie jsou všude kolem nás“ (Dahlberg 2015). Jedním z úkolů krajinné ekologie je výzkum sekundární krajinné struktury, kde základem je mapování využití krajiny a krajinného pokryvu, vymezování krajinných jednotek a jejich klasifikace (Vondrušková 1994). To není tak problematické u polí, luk, pastvin - bez stromů. Tato práce ve třech případových studiích uvádí příklady toho, že jakmile se do polí, luk a pastvin mísí dřeviny nebo se do lesů vmísí pole, louky a pastviny, tedy jakmile máme co do činění s agrolesnictvím, vymezit pak krajinné jednotky může být komplikované. Ve třech studiích ukazuji, jaké mohou být přístupy k mapování agrolesnictví a jak je agrolesnictví prezentováno v mapováních krajiny jak ve starší a nedávné minulosti, tak v současnosti.

První kapitola představuje stručně a z několika úhlů téma agrolesnictví – přehled agrolesnických praktik s důrazem na Evropu, souhrn ekosystémových služeb, jež agrolesnictví poskytuje, nástin historie agrolesnictví, současné ohrožení agrolesnických systémů, politické problémy agrolesnictví a především odhady rozlohy agrolesnictví v různých měřítcích.

Ve druhé kapitole je k nalezení článek „Quantifying inconsistencies in old cadastral maps and their impact on land-use reconstructions”, který předkládá analýzu evidence jednotlivých pozemků ve čtyřech částech Františkovského katastru z poloviny 19. století. Ten je zajímavý mimo jiné tím, že na rozdíl od dnešního katastru nemovitostí eviduje několik kultur využití půdy, které lze označit jako agrolesnické (Krčmářová 2015). Právě v evidenci některých z těchto agrolesnických kategorií jsou části Františkovského katastru podle naší případové studie nejednotné.

Ve třetí kapitole (článek „Changes and continuity of wood-pastures in the lowland landscape in Czechia”) je prezentován výzkum časoprostorové dynamiky pastvin s dřevinami, založený opět na Františkovském katastru. Práce zahrnovala i vlastní vymezování ploch této obtížné kategorie.

Čtvrtá kapitola, v níž je článek “The current status of orchard meadows in Central Europe : Multi-source area estimation in Saxony (Germany) and the Czech Republic” se zabývá jiným typem tradičního agrolesnictví, lučními sady. Snaží se vymezit, kolik je reálně lučních sadů v Česku a v Sasku. V případě Saska používáme několik zdrojů, prostorových databází, vymezujících luční sady. Tyto zdroje se ne vždy shodují ve vymezení jednotlivých lučních sadů.

Zavěrečná kapitola začíná nejprve samostatnými komentáři ke vztahu druhé až čtvrté kapitoly k tématu dizertační práce. V těchto komentářích se snažím zpětné reflektovat tyto studie, zhodnotit, s čím novým přišly a jaké jsou jejich nedostatky. Dále diskutuji přístupy k mapování agrolesnictví, jež byly použity ve studiích prezentovaných v této práci i v jiných studiích, a přináším náměty pro další výzkum agrolesnictví v českém prostředí.

2. Agrolesnictví – literární rešerše

2.1 Definice a kontexty

Pojem agrolesnictví poprvé použil v polovině 70. let 20. století kanadský lesník John Bene a přivedl mezinárodní pozornost k významu stromů v zemědělství. Následně bylo v roce 1978 vytvořeno Mezinárodní centrum pro výzkum v agrolesnictví (International Centre for Research in Agroforestry – ICRAF, nyní používá značku World Agroforestry) se sídlem v Nairobi. V 80. letech byla přijata definice agrolesnictví jako označení pro systémy využití půdy a technologie/praktiky, kde jsou dřeviny úmyslně používány na jedné jednotce půdy spolu se zemědělskou plodinou a/nebo se zvířaty v určité podobě prostorového nebo časového uspořádání. V agrolesnických systémech probíhají ekologické a ekonomické interakce mezi složkami těchto systémů. (Lundgren, Raintree 1982)[1]. Tuto definici dodnes používá např. FAO (2015).

Podle Naira (1993)[2] je základem agrolesnictví úmyslné pěstování stromů a zemědělské plodiny a/nebo zvířat ve vzájemných interakcích za účelem násobení užitku z jedné výrobní jednotky.

Podle americké asociace pro agrolesnictví mírného pásu (AFTA) je agrolesnictví intenzivní způsob využití půdy, který optimalizuje užitek z biologických interakcí vzniklých úmyslnou kombinací dřevin se zemědělskou plodinou a/nebo se zvířaty (AFTA 2015)[3].

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[1] Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agro-forestry systems there are both ecological and economic interactions between the different components.

[2] Agroforestry is purposeful growing or deliberate retention of trees with crops and/or animals in interacting combinations for multiple products or benefits from the same management unit. This is the essence of agroforestry.

[3] Agroforestry is an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock.

Přesnou definici agrolesnictví se pokusil formulovat Somarriba (1992)[4], podle nějž jde o způsob pěstování, který kombinuje tři základní podmínky:

1. Jsou zde alespoň dva biologické druhy, které mezi sebou mají biologickou interakci.
2. Alespoň jeden z těchto druhů je dřevina.
3. Alespoň jeden z těchto druhů je pěstován jako krmivo nebo jako zemědělská plodina.

Podle Sinclaira (1999)[5] nejde jen o praktiky, ale také o interdisciplinární přístup, který uvažuje zároveň dřeviny, byliny a traviny, zvířata a lidi a jejich interakce navzájem v zemědělských a lesnických systémech. Zahrnuje kromě jejich produktivity ekosystémový přístup zaměřený na stabilitu, udržitelnost a spravedlnost způsobu využití půdy. Tento přístup zahrnuje ekologické, ekonomické i sociální aspekty.

Podle ICRAF je agrolesnictví interakce zemědělství a stromů, včetně zemědělského využití stromů. Zahrnuje stromy na farmách a v zemědělské krajině, zemědělství v lesích a podél lesních okrajů a produkci stromů. Interakce mezi stromy a ostatními složkami zemědělství mohou být významné v několika měřítcích: v měřítku půdních bloků (kde spolu rostou stromy a plodiny), v měřítku farmy (stromy mohou poskytovat krmivo pro zvířata, palivo, jídlo, úkryt nebo příjem ze stavebního dříví) a měřítku krajin (kde kombinace zemědělského a lesnického využití půdy určuje poskytované ekosystémové služby). Agrolesnictví je dynamický ekologický způsob řízení přírodních zdrojů, který skrze interakci stromů na zemědělské půdě diverzifikuje a zajišťuje

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[4] Form of multiple cropping which satisfies three basic conditions: 1. There are at least two species that interact bilogically, 2. At least one of the species is a woody perennial, 3. At least one of the plant species is managed for forage, annual or perennial crop production.

5 The approach is interdisciplinary and combines the consideration of woody perennials, herbaceous plants, livestock and people, and their interactions with one another in farming and forest systems. It embraces an ecosystem focus considering the stability, sustainability and equitability of land-use systems, in addition to their productivity (see Conway, 1987; Marten, 1988). Consideration of social as well as ecological and economic aspects is implied.

produkci za účelem zvýšení sociálního, ekonomického a environmentálního užitku uživatele půdy na všech úrovních (ICRAF 2020)[6].

Podle Sinclaira (1999) může být používání pojmu agrolesnický systém matoucí, neboť agrolesnictví je zřídka používáno v celém faremním systému. Většinou se agrolesnictví praktikuje pouze v několika sektorech (produkčních nikách) zemědělské či lesnické produkce určité farmy. Hlavním komunikačním prostředkem v oboru agrolesnictví je přitom časopis *Agroforestry systems*. Hojně užívaná definice (Lundgren, Raintree 1982) i jiné uvádí, že se jedná o kombinaci zemědělské plodiny a/nebo chovu zvířat s dřevinami na jedné hospodářské jednotce. Vymezení této jednotky samozřejmě záleží na měřítku. Agrolesnictví tak může být záležitostí jednoho pozemku (např. luční sady ve střední Evropě), jedné farmy (např. celé farmy v Portugalsku, Španělsku nebo Řecku jsou agrolesnické) nebo celé krajiny (den Herder et al. 2015). Specifikace uvedená na webových stránkách Světového agrolesnického centra [tedy že interakce mezi stromy a ostatními složkami zemědělství mohou být důležité v několika měřítcích: v měřítku půdních bloků (kde spolu rostou stromy a plodiny), v měřítku farmy (stromy mohou poskytovat krmivo pro zvířata, palivo, jídlo, úkryt nebo příjem ze stavebního dříví) a měřítku krajiny (kde kombinace zemědělského a lesnického využití půdy určuje poskytované ekosystémové služby)] je problematická a zbytečně pojem agrolesnictví rozmělňuje, protože kombinace lesních, polních a travních krajinných plošek je pro krajinnou mozaiku běžná. Zde se přidržíme chápání agrolesnictví jako prostorové nebo časové kombinace pěstování plodin a/nebo chovu zvířat na jednom pozemku (půdním bloku, hospodářské jednotce, biotopu, ekotopu) spolu s dřevinami za účelem prospěchu z ekologických a ekonomických interakcí.

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[6] Agroforestry is the interaction of agriculture and trees, including the agricultural use of trees. This comprises trees on farms and in agricultural landscapes, farming in forests and along forest margins and tree-crop production, including cocoa, coffee, rubber and oil palm. Interactions between trees and other components of agriculture may be important at a range of scales: in fields (where trees and crops are grown together), on farms (where trees may provide fodder for livestock, fuel, food, shelter or income from products including timber) and landscapes (where agricultural and forest land uses combine in determining the provision of ecosystem services). Agroforestry is a dynamic, ecologically based natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels

O agrolesnictví můžeme uvažovat v několika příbuzných konceptuálních kontextech. Dřeviny v agrolesnických systémech mohou být příklady stromů rostoucích mimo les nebo nelesní dřevinné vegetace (*trees outside forest, non-forest woody vegetation*), mezi něž patří solitérní stromy, aleje nebo remízky (Novotný, Skaloš, Plieninger 2017; Plieninger et al. 2012; Plieninger 2012; Demková, Lipský 2015) nebo rozptýlených stromů v krajině (*scattered trees*), jejichž krajinotvorný význam je nepoměrný s významem jednotlivých stromů v lesních porostech (Manning, Fischer, Lindenmayer 2006; Manning, Gibbons, Lindenmayer 2009; Gibbons et al. 2008; Fischer, Stott, Law 2010). Dále je agrolesnictví jedním z příkladů sdílení půdy pro různé funkce (*land sharing*), v tomto případě se jedná o lesnickou a zemědělskou produkci (Manning, Fischer, Lindenmayer 2006; Mann et al. 2018; Torralba et al. 2018). Některé agrolesnické systémy mohou být zemědělskou krajinou s vysokou přírodní hodnotou (*high nature value farmland*), tedy krajinou s nízkou intenzitou antropogenního využívání přispívajícího k velké biodiverzitě. Mezi takové prvky zemědělské krajiny patří mj. *dehesa, bocage,* tradiční vinice, olivové háje a extenzivně využívané travní porosty (Pantera et al. 2018; Kizos et al. 2012; Plieninger et al. 2015a; Moreno et al. 2018). Agrolesnické systémy bývají někdy uvažovány jako sociálně-ekologické systémy (nejen ekologické systémy, ekosystémy), tedy systémy se silnou interakcí mezi ekologickými a sociálními fenomény (Torralba et al. 2018; Garrido et al. 2017; Hartel, Plieninger 2014). Některé agrolesnické praktiky, zejména některé pastviny se stromy v Anglii nebo v Rumunsku, jsou příkladem využití území se starými stromy. Jiným takovým územím jsou obory (Moreno et al. 2018; Horák 2017; Moga et al. 2016; Kirby 2015; Gibbons et al. 2008; Butler, Alexander, Green 2002).

2.2 Klasifikace agrolesnictví

Spolu s rozvojem oboru agrolesnictví v 80. letech 20. století se vytváří různé klasifikace agrolesnických systémů. Nair (1985) dělí agrolesnictví podle strukturních prvků na agrisilvikulturní (*agrisilvicultural systems*; kombinace dřevin a zemědělských plodin), silvopastorální (*silvopastoral systems;* kombinace dřevin a pastvy), agrosilvopastorální (*agrosilvopastoral systems;* kombinace dřevin, zemědělských plodin a pastvy) a ostatní (např. chov ryb a pěstování stromů) systémy. Dalším kritériem je pro něj prostorové a časové uspořádání strukturních prvků a jejich funkce. Sinclair (1999) uvádí, že agrolesnictví nemusí být uzavřený systém jediné farmy, ale je spíše částí výrobního zemědělského procesu. Agrolesnické praktiky člení podobně jako Nair podle strukturních prvků, dál ovšem agrolesnictví rozlišuje podle hlavního využití půdy (např. pastva v lese/ stromy na pastvině) a typů dřevinných porostů podle přirozenosti (přirozený les/ vysázený les/ dřevinné porosty se zemědělskou produkcí).

V této době se hlavní pozornost v souvislosti s agrolesnictvím upírá na tropickou oblast. Zvláště v posledních dvaceti letech se však uplatňují agrolesnické koncepty na mírný pás Evropy a řada tradičních praktik formujících kulturní krajinu se zde identifikuje jako agrolesnické (Zerbe 2019; Moreno et al. 2018). Mosquera-Losada et al. (2008) tak rozlišují v Evropě tyto hlavní agrolesnické praktiky:

- silvoorební agrolesnictví – stromy s velkým rozestupem, mezi nimiž je pěstovaná zemědělská plodina. Může se jednat o řady stromů na polích (*alley cropping*), rozptýlené stromy a pásy stromů kolem pozemků (živé ploty, větrolamy).
- lesní zemědělství – získávání plodin z lesa, např. hub, léčivých rostlin, bobulí a medu.
- břehové porosty – pásy dřevin mezi zemědělskou plochou a vodním tokem/vodní plochou s funkcí ochrany vody.
- zelený úhor s dřevinami (zušlechťovací úhor) – zejména s bobovitými dřevinnými rostlinami, dnes se při používání umělých hnojiv v podstatě nepoužívá. Příklad časové kombinace plodiny a dřeviny na jednom pozemku.
- víceúčelové stromy – stromy s užitkem ovoce, plodů (např. žaludů), palivového dřeva, krmiva, stavebního dříví, silice a pryskyřice pěstované na zemědělském pozemku.
- silvopastorální agrolesnictví – stromy na pastvinách, ať už v hustých (pastva v lese) nebo v řídkých (pastviny s rozptýlenými stromy) porostech. Sem může patřit i chov zvěře v oborách nebo chov sobů v boreální oblasti.

Je patrné, že agrolesnické praktiky se mohou prostorově překrývat. Například víceúčelové stromy mohou být součástí silvoorebního a silvopastorálního agrolesnictví i břehových porostů. Silvoorební a silvopastorální agrolesnictví může být praktikováno na jednom pozemku v časové posloupnosti (např. pastva na úhoru). Lesní zemědělství je praktikováno mj. v silvopastorálních plochách.

Z předchozího výčtu je zřejmé, že takové pojetí agrolesnictví je velmi široké. Podle Gravese et al. (2008) si přitom velká část zemědělců v Evropě, kteří slyšeli pojem agrolesnictví, pod ním představí spojení stromů a zemědělské plodiny nebo zvířat. Agrolesnictví v užším pojetí jsou především silvoorební a některé silvopastorální praktiky, tedy zemědělské pozemky, kde je prostorově kombinované pěstování stromů a hospodářských plodin, případně pastva hospodářských zvířat.

Tradičními silvopastorálními krajinami či krajinnými prvky v Evropě jsou pastviny s dřevinami (*wood-pastures*, *Hutweide*) (Hartel, Plieninger, Varga 2015), dubové pastevní a orební lesy v Mediteránu – např. *montado* (Portugalsko) (Pinto-Correia, Azeda 2017) a *dehesa* (Španělsko) (Garrido et al. 2017). S různými silvopastorálními praktikami jsou spojeny tradiční managementy jako komolení (*pollarding* – pravidelné ořezávání výhonů stromů ve výšce 1,5 m – 5 m) (Dreslerová, Sádlo 2000; Kirby 2015) nebo panáž (*pannage* – pastva prasat na žaludech) (Szabó 2013). Tyto praktiky sahají až do pravěku. Tradiční novověké agrolesnictví v Evropě představují ovocné sady se sekundárním využitím (*Streuobst, pré-verger* - hlavně od 18., 19. století) (Herzog 1998), ať už s ornou půdou (polní sady), loukou (luční sady) nebo pastvinou (pastevní sady). Nové agrolesnické systémy se vyznačují přesným uspořádáním dřevin do řad. Může se jednat o výmladkové plantáže rychle rostoucích dřevin v kombinaci s pěstováním zemědělských plodin. Nebo může jít o pěstování cenných dřevin s velkou výškou kmene, které na rozdíl od tradičního agrolesnictví s širšími korunami nezastiňují průvodní zemědělskou plodinu (Nerlich, Graeff-Hönninger, Claupein 2013; Eichhorn et al. 2006).

2.3 Význam agrolesnictví v krajině, poskytované ekosystémové služby

Agrolesnictví jsou způsoby využití území, které poskytují celou řadu ekosystémových služeb (Fagerholm et al. 2016). V porovnání se zemědělstvím bez stromů jsou významné zejména regulační ekosystémové služby, jako snižování eroze a zadržování živin (Kay et al. 2018; Moreno et al. 2018). Agrolesnictví snižuje oproti obyčejnému lesnictví riziko požárů, protože jsou zde větší mezery mezi stromy, a tak se nemůže požár tak snadno šířit (Damianidis et al. 2020). Mitigace klimatické změny je podpořena ukládáním uhlíku ve stromech na zemědělské půdě (Hernández-Morcillo et al. 2018; Mosquera-Losada et al. 2018b). Adaptace na klimatickou změnu je posílena stíněním půdy korunami stromů a zadržováním vody kořeny stromů (Ghaley, Vesterdal, Porter 2014). Obecně se má za to, že agrolesnictví má velký význam pro biodiverzitu v krajině, ačkoliv podle nového review to tak jednoznačné není (Mupepele, Keller, Dormann 2020). Nicméně např. pastviny se stromy v Rumunsku hostí více druhů ptáků než otevřené pastviny nebo lesy (Hartel et al. 2014), jsou velmi důležitým stanovištěm pavouků (Gallé et al. 2017) a datlovitých (Dorresteijn et al. 2013). Tento význam je způsoben mimo jiné tím, že na tamějších pastvinách jsou starší stromy než v hospodářských lesích (Hartel et al. 2013; 2018). Luční sady představují významný biotop ptáků, motýlů, saproxylického hmyzu a travních společenstev (Horák 2014; Horák et al. 2018; Kajtoch 2017; Žarnovičan, Kollár, Škodová 2017). Koexistence travního porostu a stromů či keřů podmiňuje vysokou strukturní diverzitu a mimořádnou prostorovou proměnlivost ekologických faktorů, např. světla, dostupnosti živin a vlhkosti půdy (Garbarino, Bergmeier 2014; Bergmeier, Petermann, Schröder 2010; Bergmeier, Roellig 2014). Dřeviny na pastvinách zvyšují diverzitu cévnatých rostlin (Vojta, Volařík, Kovář 2020) i na krajinné úrovni (Jakobsson, Lindborg 2015). Agrolesnické systémy jsou důležité pro svou estetickou (Pinto-Correia et al. 2011; Surová, Pinto-Correia, Marušák 2014) a rekreační hodnotu (Ohnesorge et al. 2015), mohou být významné pro komunitní soudržnost (Bieling, Konold 2014) a přenos kulturních zvyklostí (Sutcliffe, Öllerer, Roellig 2014).

Stromy na zemědělské půdě jsou ceněny zemědělci a dalšími stakeholdery. Důvodem, který uvádějí, je např. to, že stromy poskytují stín pro pasoucí se zvířata (Hartel, Réti, Craioveanu 2017), brání erozi (Blanco et al. 2020), zvyšují biodiverzitu a estetiku krajiny (García de Jalón et al. 2017), zvyšují diverzitu faremní produkce a jsou symbolem tradice (Rois-Díaz et al. 2018; Roellig et al. 2015). Tyto pozitivní aspekty mají ovšem své trade-offs. Mezi negativy může být nižší výnos zemědělské plodiny (Rois-Díaz et al. 2018; Kay et al. 2018) a vyšší nároky na práci (García de Jalón et al. 2017). Podle modelů produkce je agrolesnictví celkově výnosnější než pěstování stromů a zemědělských plodin zvlášť kvůli komplexnějšímu využívání zdrojů a vzájemným interakcím. Tento efekt lze vyjádřit pomocí tzv. *land equivalent ratio* (poměr mezi plochou, kde by probíhalo oddělené zemědělské a lesnické hospodaření, a agrolesnickou plochou tak, aby bylo dosaženo stejného výnosu) (Graves et al. 2010)

2.4 Vývoj agrolesnictví a jeho ohrožení

Agrolesnictví je vlastně nové slovo pro staré praktiky (Nerlich, Graeff-Hönninger, Claupein 2013). Pastva v lese probíhala prakticky od počátku zemědělství a kontrasty mezi jednotlivými krajinnými segmenty (louka, pastvina, les) byly malé (Vera 2000; Dreslerová, Sádlo 2000). Od 18. století dochází k racionalizaci využití území a prostorově se odděluje pěstování lesa od zemědělství (Sádlo et al. 2005; Jørgensen, Quelch 2014) a pastva v lese je zakazována (Bergmeier, Petermann, Schröder 2010). U nás k tomu definitivně dochází lesním zákonem z roku 1960 (NSČSSR 1960). Vítězí takový přístup k managementu krajiny, kdy jednotlivé krajinné segmenty mají přísně určené funkce (Manning, Fischer, Lindenmayer 2006). V českém kontextu na tento proces poukázala Krčmářová (2015; Krčmářová and Jeleček 2017). Nicméně např. vrchol lučních a polních sadů lze ve střední Evropě doložit až v polovině 20. století (Herzog 1998). Zapomínání starých agrolesnických praktik je vlastně projevem úbytku tradičních kulturních krajin (Antrop 2005). V nové době se znovu objevují výhody kombinace zemědělství a lesnictví (Nerlich, Graeff-Hönninger, Claupein 2013).

Rozloha tradičního agrolesnictví se zmenšuje po celé Evropě a je zdokumentována na krajinách typu *dehesa* a *montado* ve Španělsku, resp. Portugalsku (Regato-Pajares et al. 2005; Costa et al. 2011; 2014), na různých typech nelesní dřevinné vegetace ve východním Německu (Plieninger et al. 2012) a v Česku (Novotný, Skaloš, Plieninger 2017), na pastvinách s dřevinami v Česku (Pereponova, Skaloš 2019; Forejt et al. 2017), na Slovensku (Wiezik et al. 2018), v Rumunsku (Drăgan, Mureşan, Benedek 2019) a v Maďarsku (Varga et al. 2015) a na lučních sadech v Německu (Plieninger et al. 2015b; Herzog 1998).

Úbytky tradičních agrolesnických systémů v posledních desetiletích způsobuje extenzifikace využívání zemědělské krajiny na jedné straně a jeho intenzifikace na straně druhé (Bičík et al. 2010). Extenzifikace se projevuje opouštěním agrolesnických pozemků a jejich zarůstáním v sekundární lesy, zaváděním typů využití území s nižším vkladem práce (např. lesy). Intenzifikace může znamenat buď přeměnu v typy využití půdy s větším antropogenním zatížením (orná půda bez stromů, zastavěná plocha) nebo větší pastevní tlak a tím omezená regenerace dřevin (pastvina bez stromů; Bergmeier et al. 2010).

Velmi diskutovaným tématem je reprezentace agrolesnických systémů ve společné zemědělské politice EU. Až úsilím odborníků a zemědělců napříč EU (Beaufoy et al. 2015) se podařilo do společné zemědělské politiky zařadit nebo upravit některé prvky tak, aby agrolesnictví dostávalo patřičnou podporu. Např. v současnosti je součástí programu rozvoje venkova (Rural Development Programme) opatření 8.2 – podpora pro zakládání a údržbu agrolesnických systému. Problematické je, že ne každá země implementuje tato opatření do své politiky (Mosquera-Losada et al. 2018a). V minulosti však byla taková praxe, kdy kvůli splnění limitů v hustotě porostu byly káceny stromy na pastvinách, čímž docházelo k nesmyslné ekologické škodě (Jakobsson, Lindborg 2015; Sandberg, Jakobsson 2018).

2.5 Mapování agrolesnictví, odhady rozloh agrolesnictví

Existují pokusy monitorovat nebo alespoň odhadovat rozlohu agrolesnictví v různých měřítcích. Důležité je to z důvodu sledování jejich vývoje v kontextu změn krajiny nebo kvůli evidenci jejich významu – jaké je množství poskytovaných ekosystémových služeb, např. ukládání uhlíku (Nair, Kumar, Nair 2009). V planetárním měřítku se o to pokusili Zomer et al. (2009) nebo Nair et al. (2009). První jmenovaní prolnuli globální data o rozsahu zemědělského využití půdy s globálními daty o pokryvu stromů v rastru o velikosti 1 km. Z toho vychází kontinuum výskytu stromů v různých zemědělských krajinách, přičemž 46 % zemědělské půdy na světě má alespoň 10% pokryv stromů. Druzí prostě odhadli, že agrolesnictví se týká asi 20 % globálně využívané orné půdy, 15 % pastvin a 5 % lesů. Jak ovšem poznamenávají Nair et al. (2009), odhadnout rozlohu agrolesnictví je složité, protože neexistují postupy, jak vymezit oblast ovlivněnou stromy. To je zvláště problematické v systémech bez pravidelného rastru stromů, u větrolamů nebo dřevin na hranicích pozemků. Záleží také na chápání pojmu agrolesnictví, protože vzali-li bychom široké pojetí, pak většina Evropy je agrolesnická. V evropských lesích se totiž běžně sbírají bobule a houby (*forest farming*) a prakticky celá severní Skandinávie je spásána polodomestikovanými soby v jednotlivých ohradách o rozloze desítek km^2.

V evropském projektu CORINE Land Cover (EEA 1994) je třída 2.4.4 Agrolesnictví, která však zahrnuje především agrolesnictví mediteránní oblasti se zápojem korun 10 % - 30 % (Copernicus 2020). Třída byla zaznamenána na 3,3 milionech ha pouze ve Španělsku, Portugalsku, Itálii, Francii a Rakousku (den Herder et al. 2015). Podle Rois-Díaz, Mosquera-Losada, Rigueiro-Rodríguez (2006) však silvopastorální agrolesnictví (nemluvě o jiných typech agrolesnictví) může být obsaženo v 10 třídách klasifikace CORINE. Nevhodnost použití CORINE Land Cover pro mapování agrolesnictví vyplývá také z toho, že minimální mapovací jednotka zde má 25 ha, což se hodí nanejvýš pro agrolesnické krajiny Středomoří nebo pastevní krajinu ve Skandinávii, nikoliv pro jednotlivé plošky lučních sadů apod.

Podle literární rešerše (den Herder et al. 2015) se v Evropě provozuje agrolesnictví na asi 10,6 milionech ha (kromě krajin s pastvou sobů ve Skandinávii), nejvíce ve Španělsku, Řecku, Portugalsku a v Itálii. V tomto rešeršním odhadu jsou pro Česko zahrnuty pouze agrolesnické sady podle Herzoga (1998).

V Evropské unii odhadli rozlohu agrolesnictví den Herder et al. (2017) pomocí projektu LUCAS (Land Use/Cover Area frame Survey), za nímž stojí Eurostat. Projekt LUCAS sestává z více než 270 000 bodů v 28 státech EU a zaznamenává desítky atributů o krajinném pokryvu a využití půdy v jednotlivých bodech. Pomocí kombinace atributu o zemědělském využití půdy a atributu o dřevinném krajinném pokryvu lze určit, zda se v daném bodě praktikuje agrolesnictví. Uvedená studie dochází k závěru, že v EU je asi 15,4 milionu ha agrolesnictví (8,8 % zemědělské půdy), z toho 15,1 milionu ha silvopastorální plochy. Nejvíce je agrolesnictví zastoupeno v mediteránní oblasti – Španělsko, Portugalsko, Itálie, Řecko, Bulharsko. Databáze LUCAS byla použita i u jiných úloh pro odhady různých typů agrolesnictví, např. pastvin s dřevinami (Plieninger et al. 2015a), domácích zahrad, silvoorebního agrolesnictví, břehových porostů a živých plotů (Mosquera-Losada et al. 2018b), solitérních stromů (Santiago-Freijanes et al. 2018) nebo lučních sadů (Forejt, Syrbe 2019). Kromě databáze LUCAS se pro odhady rozlohy agrolesnických systémů využívají lokální statistiky. Např. Herzog (1998) z národních statistik odhadoval, že se v Evropě nachází 10 000 km^2 ploch s rozptýlenými ovocnými stromy. Eichhorn et al. (2006) na základě oficiálních statistik a osobních kontaktů odhadl rozlohu orebních agrolesnických systémů v sedmi evropských zemích. Podle Sinclaira (1999) je však pro to, aby byla nějaká praktika popsaná jako agrolesnictví, nutné, aby byl nějaký vztah mezi stromy a lidmi („*The key integration in agroforestry is, in fact, amongst people and trees, in as much as it is how people use trees that ultimately determines whether an activity is usefully described as agroforestry*", s. 167). Z toho vyplývá, že ne každý strom na zemědělském pozemku je užitečné označovat jako agrolesnický prvek. Dřevina by tam měla být za nějakým účelem, měla by tam být nějaká interakce mezi zemědělskou činností a dřevinami. Z toho důvodu je použití databáze LUCAS za účelem odhadu rozlohy agrolesnictví problematické, protože ne každá plocha s výskytem stromů a zároveň znaky pastvy je silvopastorální agrolesnictví.

Existuje celá řada případových studií na menších územích, v nichž jsou vymezovány agrolesnické plochy na základě leteckých nebo satelitních snímků jako polygony pomocí on-screen digitalizace. Tento přístup byl použit u krajin, které jsou známé velkým zastoupením agrolesnictví, ať už se jedná o portugalské *montados* (Costa et al. 2011), španělské *dehesas* (Plieninger 2006) nebo řecké spásané doubravy (Schaich et al. 2015). Pro identifikaci těchto krajinných segmentů byla nejčastěji použita metoda hustoty porostu (>5 stromů/ha, Plieninger 2006 maximálně 80 stromů/ha). Garbarino et al. (2011) aplikovali pro příklad modřínových pastvin v italských Alpách také on-screen manuální segmentaci leteckých snímků. Tyto segmenty pak klasifikovali pomocí objektově orientované klasifikace podle zápoje korun, kde pastviny s dřevinami měly interval 10% - 30% zápoj korun. Plieninger et al. (2015b) v krajině Švábské Alby s velkým zastoupením lučních sadů tyto agrolesnické prvky identifikovali vizuálně na leteckých snímcích jako travní porosty s 20 – 100 stromy/ha. V hlavním městě Česka, Praze, byly luční sady identifikovány na leteckých snímcích podle pravidelné vzdálenosti mezi stromy, pravidelné velikosti korun stromů a snadno rozeznatelné vnější hranici krajinného segmentu (Janeček et al. 2019). Dalším přístupem je vizuální detekce jednotlivých prvků nelesní dřevinné vegetace jako jsou aleje, skupiny stromů, živé ploty, remízky nebo solitérní stromy (Plieninger et al. 2012; Demková, Lipský 2015; Novotný, Skaloš, Plieninger 2017), tedy body, plochy a linie v souladu s konceptem ploška – koridor – matrice (Forman, Godron 1986). Ty mohou být součástí agrolesnických systémů.

K identifikaci agrolesnictví v historických krajinách často slouží i staré mapy. Mezi hojně využívané zdroje patří staré katastrální mapy, které byly použity pro identifikaci různých způsobů zemědělského využití lesa (Szabó, Hédl 2013), různých agrolesnických praktik (Krčmářová 2015; 2016; Agnoletti 2007), pastvin s dřevinami (Vojta, Drhovská 2012; Pereponova, Skaloš 2019), nebo obecně nelesní dřevinné vegetace (Skaloš, Engstová 2010; Skaloš et al. 2015). Mapy středního měřítka byly použity pro identifikaci pastvin s dřevinami a nelesní dřevinné vegetace (Plieninger 2012; Varga et al. 2015).

3. Quantifying inconsistencies in old cadastral maps and their impact on land-use reconstructions

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Quantifying inconsistencies in old cadastral maps and their impact on land-use reconstructions

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ABSTRACT

Old cadastral maps represent a historical reference dataset for long-term land-use reconstructions. This study presents identification of inconsistencies in the nineteenth century Franziscean cadastre, one of the largest sets of old cadastral maps worldwide, by comparing three versions of the maps and written documents created in the same period. We identified all parcels and their land-use in the four sub-sources in six study areas. The overall share of inconsistencies among 5 771 identified parcels is 7.4%, with the biggest share of inconsistency in agroforestry and forestry classes. The most frequent inconsistencies are of 'Not differentiable land use' (n = 212) and 'Different land-use' categories across the sub-sources (n = 113). We conclude that the frequency of uncertainties in old cadastral maps may limit the validity of historical land-use reconstructions, affecting the eventual restoration and management efforts based on such data. We provide a summary for the use of Franziscean cadastre.

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1. Introduction

Human activity significantly alters natural systems. In recent decades the extent of such alternations was increasingly manifested by urbanisation and agricultural expansion (Science for Environment Policy, 2016; Song et al., 2018). Such interventions proved to have a significant impact, among others, on the loss of biodiversity, changes in energy fluxes, or soil degradation (Arneth et al., 2017; Foley, 2005). While current land-cover dynamics are mostly analysed by remote sensing methods (Gerard et al., 2010), understanding the long-term trajectory and nature of these changes must rely on accurate data about historical land-use. Such information is fundamental for applications ranging from landscape restoration to habitat conservation and is derivable from methods used in historical ecology (e.g., pollen records or tree-ring analysis; Röpke et al., 2011), archaeological evidence (e.g., historical demography; Klein Goldewijk & Verburg, 2013) or by use of archive data, mainly old cartographic sources, carrying information on land-use (Fuchs et al., 2015).

Old maps represent a vital source of information for land-use reconstruction, because of their spatial resolution to the level of individual plots or patches with difference in land-use. Historical spatial data is used widely to trace the impact of human activity on long-term land-use development changes across regions (Fuchs et al., 2015) and for land management applications, to identify valuable features for landscape planning (Skaloš & Kašparová, 2012), study habitat continuity important for conservation (Vojta & Drhovská, 2012), analyse forest extent and structure (Kaim et al., 2016; Müllerová et al., 2014), monitor loss of trees outside the forest (Plieninger, 2012), evaluate

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morphological and vegetational variations of land for landscape planning interventions (Tortora et al., 2015) or to study land-use conversion and its driving forces as to understand either the negative processes of land abandonment (Kanianska et al., 2014) or landscape fragmentation (Dewan et al., 2012).

Along with cartographic sources, additional information about attributes (land tenure, taxation) of a parcel is essential as it allows for a deeper insight into the societal relation to landscape. As for its sustainability analysis, they also allow us to explore past modes of agriculture (Krausmann, 2004) or parcel fragmentation (Sklenička et al., 2017). Such additional information is provided by the old cadastral apparatus, which includes numerical data for tax purposes, ownership and additional information made during the mapping campaign. Most studies have utilized only maps, while leaving the additional information behind, until now.

The use of old cadastral sources, while increasing among scholars from various disciplines, raises the question of the sources' limitations. Uncertainties resulting from these limitations are often admitted but less frequently addressed during the data analysis. Also, these uncertainties are documented insufficiently by empirical research. The sources of uncertainty (Forejt et al., 2018; Leyk et al., 2005; Yang et al., 2014) originated in (i) temporal limitation also known as lack of diachronic depth – sources are referring to a single time point in the past, which contrasts the dynamically evolving landscape; (ii) deliberate distortion of information/localization, e.g., for military purposes; (iii) technical errors during the original survey (e.g., by technological limits or misunderstanding of mapping criteria by individual surveyors), or the consecutive digitalization and transformation/reprojection; (iv) semantic constraints–different meaning of land-use classes in different cartographic works; and (v) parcel boundary distortion by combining the information about land tenure and a specific land-use class. These uncertainties may fundamentally infringe upon the measures and interventions designed with the use of historical land-use reconstructions. Deriving a more accurate idea on the possible extent of these uncertainties has faced the lack of cross-comparative data.

In this respect, the Franziscean (also referred to as Stable) Cadastre is a representative example of the information-rich old cadastral apparatus that stands as a source of major importance for land-use change research in Central Europe. The cadastre was produced in the 19th century and intended to cover the whole former Austrian Empire (Feucht, 2008). Due to its indisputably wide spatial extent and variety of spatial and non-spatial information, this particular data source attracts increasing attention for a variety of purposes ranging from the research of land-use change on landscape-level through the reconstruction of river channels or slope movements and loss or persistency of particular land-use classes to localization of abandoned settlements and mining sites (Dolejš & Forejt, 2019).

To contribute the current understanding to the nature of uncertainties in old cadastral maps and extend the empirical base for uncertainties assessments, in this paper, we focus our attention on the possible limitations of the land-use attribute as recorded in four different sub-sources of the Franziscean Cadastre and its cadastral maps. For the first time, we scrutinize a larger sample of all four major cadastral sub-sources looking for the possible inconsistencies in content (land-use) and geometry (spatial boundaries) of parcels. Results are used to discuss the extent and possible effects of these inconsistencies on land-use reconstructions.

2. Materials and methods

2.1. Study area

The research was conducted on six cadastral areas in Northern and Central Czechia spanning 35.1 km^2, ranging from 1.9 to 11.8 km^2 each (Figure 1). The areas were selected to represent different topography (hilly and lowland landscapes), soils and agricultural economic structure. While the final case study may hardly cover the environmental and economic diversity of the historical landscape, it

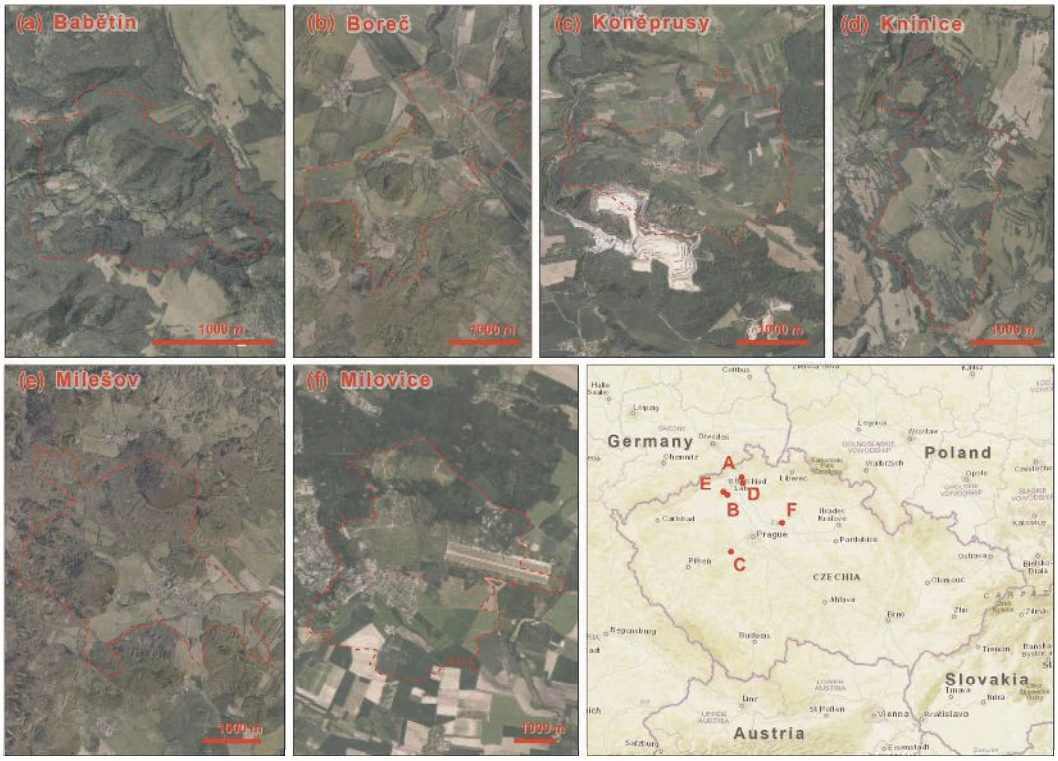

Figure 1. Location of the six studied cadastral districts in Czechia.

is finally a compromise between the representativeness of the research and feasibility of the empirical survey as the whole area of Czechia covered more than 13 000 cadastral areas (Bičík, Jeleček & Štěpánek, 2001). The simple characteristic of each area is in Table 1.

2.2. Data sources

We excerpted data for the analysis from the Franziscean cadastre. The Franziscean cadastre (named after the Austrian Emperor Francis I) is a land register produced for the former Austrian Empire between the year 1817 and the 1880 s (Feucht, 2008; Timár & Biszak, 2010) and covers at least partly current area of Czechia, Slovakia, Austria, Poland, Slovenia, Hungary, Ukraine, Croatia, Romania, Bosnia, and Serbia. The creation of the new cadastre was commenced in 1817 by an edict (ÖNB 2018) of Emperor Franz I. The cadastre was created from scratch, although there existed the previous land taxation system valid in the Austrian Empire, which was based on Josephian mapping (the 1780 s; Frajer, 2019) and represented the first measured cadastre in Austrian history. In the 1810 s it was easier to persuade the government to start new mapping because, at the same time, so-called

Table 1. General characteristics of the studied cadastral areas.

Cadastral area	Area [km^2]	Environmental setting
Babětín	1.9	200–500 m a.s.l., deep narrow valley in basaltic and sedimentary bedrock
Boreč	3.9	250–450 m a.s.l., gentle slopes under solitary volcanic hills
Koněprusy	4.4	250–450 m a.s.l., plateaus and gentle slopes in karstic area
Knínice	4.4	300–600 m a.s.l., plateaus and steep slopes on basalts
Milešov	8.8	300–800 m a.s.l., wide valley in between volcanic hills
Milovice	11.8	200–250 m a.s.l., flat lowland

2nd military mapping (middle-scaled topographical maps) has started to be mapped in the Empire and the two projects used partly common triangulation (Bumba, 2007; Ebel, 2004).

The methodology for the cadastre mapping was first described in 1818 and was further adjusted in 1824 and 1865, while the work was still in progress. Thus the methodology, including the map legend, was not unified for the whole Empire (Krčmářová, 2015). The mapping was done mostly at the scale of 1:2880 (one Vienna square inch on the map was equal to one Lower Austrian acre in the field) and, in some areas in 1:720, 1:1440, or 1:5760. The minimal mapping unit was 25 square fathoms, which is equal to approximately 90 m^2 (Ebel, 2004). The cadastre uses up to 40 land-use classes, including 10 agroforestry land-use classes (Krčmářová & Jeleček, 2017).

We analysed four elemental sub-sources of the Franziscean cadastre: Indication sketches, Original maps, Compulsory imperial imprints and Written registry (See Figure 2 for the first three).

Indication sketches are a basic cartographic tool, used to record a piece of information directly in the field. It is created in colour on cardboard. Land-use, name of the owner, class of the owner, parcel number, and house number are all indicated in this document. Indication sketches were then used to mark changes in the real state in the cadastral area (Ebel, 2004). They were made during the summer season and used for making Original maps, Compulsory imperial imprints and the Written registry during the winter season.

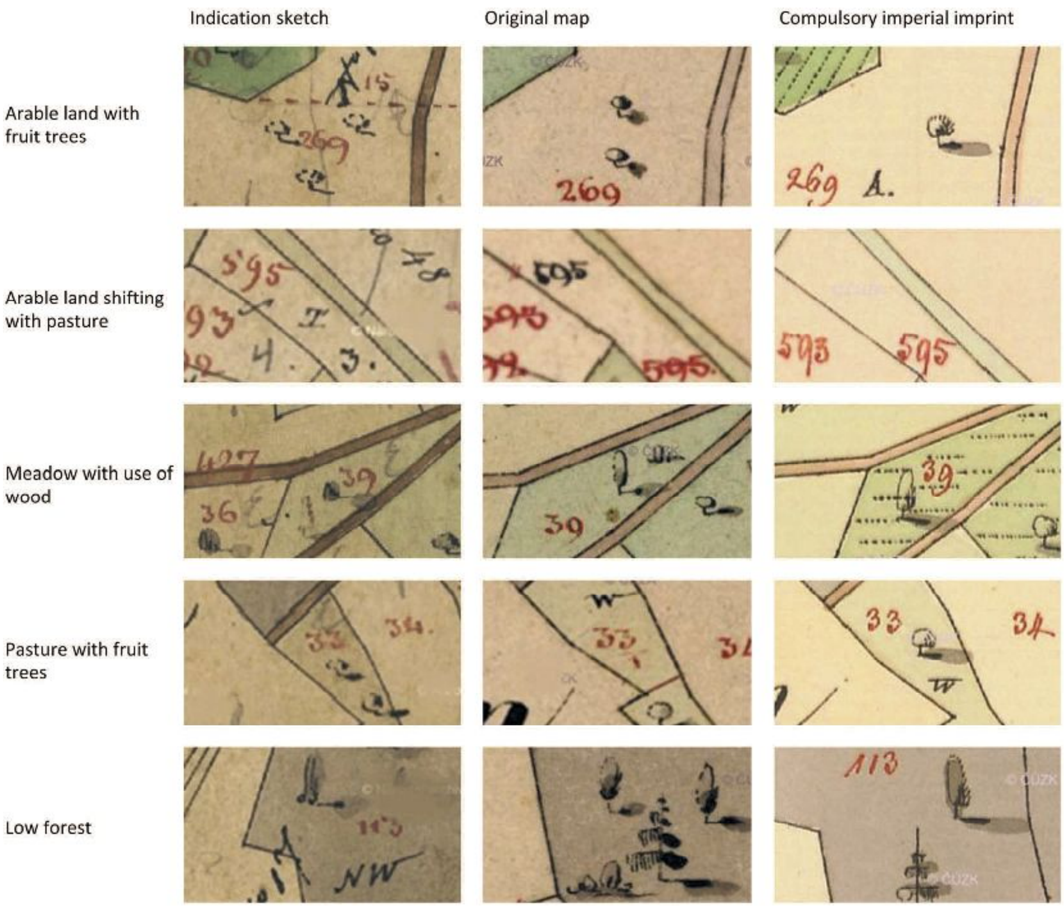

Figure 2. Comparison of identical parcels in three cartographic sub-sources of the Franziscean cadastre. The fourth analysed sub-source (Written registry) is an alphanumerical protocol. Note: (i) letter 'T' in the Indication sketches indicates the difference between arable land and arable land shifting with pasture, (ii) Original maps containing changes drawn with red colour, (iii) low forest differentiable only in Indication sketches.

Original maps are a product of office work. Made in colour on soft paper, changes from the original work were marked into Original maps in red. Original maps depict only land-use and parcel numbers, not the owner's name.

Compulsory imperial imprints are coloured lithographic copies of Original maps of the same size. The imprints were sent to the central office in Vienna to be archived, later not used for depicting additional information, therefore they are easy to read and thus widely used (Dolejš & Forejt, 2019). Compulsory imperial imprints also do not contain information about the parcel's owner.

Written registry of the Franziscean Cadastre consists of many documents for each cadastral area. We used the land parcel protocol (*Grundparzellenprotocoll*) because it includes clear evidence of owners as well as land-use classes and is listed according to the parcel numbers. Each row represents here a parcel and each parcel had a registered number, name of its owner, place of his residence, his ownership status, land-use of the parcel and its area. Attribute data of parcels were written down in the Written registry protocols.

2.3. Data processing

The data processing workflow is to be seen in Figure 3. As reference geometry, we used Compulsory imperial imprints of the Franziscean cadastre as they provide the source with the best readability. At first, we georeferenced scanned images of all map sources in the S-JTSK coordination system with Krovak projection. Using geodatabase in ArcGIS 10.6.1 (ESRI, 2018), we digitized all areal objects on the map of Compulsory imperial imprints, even if it did not have a parcel number (thus not registered in the Written registry as a parcel), which rarely occurred. The exception was groups of buildings registered under one parcel number. After object topology was checked to prevent gaps and overlaps, parcel numbers were assigned to all the parcels and their sequence was checked again.

The list of land-uses in the document was used as a land-use classification. The list called *Ausweis über die Benutzung des Bodens* is available for every cadastral area and contains cells for 40 land-uses. There were 27 land-use classes mapped within the six studied cadastral areas (Table 2). Unlike the Franziscean cadastre, we did not differentiate between burnable (usually wooden) and not burnable (usually brick or stone) houses in our analysis, because one parcel number often contains more than one building which is spatially indistinguishable in the Written registry. For each object in the created geodatabase attributes of land-uses as depicted in Compulsory imperial imprints, Original maps, Indication sketches and the Written registry were assigned. We determined the land-use only if explicitly marked with a symbol on the map. Object's land-use is thus not presumed according to

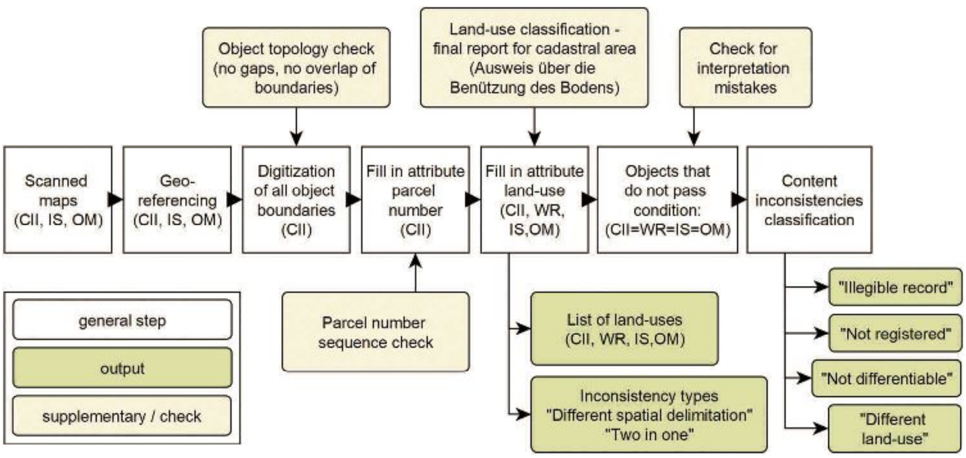

Figure 3. Data procession workflow.

Table 2. Land-use categories applied in the Franziscean cadastre.

Original	English translation
Acker	Arable land
Acker mit Obstbäume	Arable land with fruit trees
Trischfeld	Ar. land shifting with pasture
Wiese	Meadow
Wiese mit Obstbäume	Meadow with fruit trees
Wiese mit Holznutz	Meadow with use of wood
Gemüsegarten	Vegetable horticulture
Obstgarten	Fruit horticulture
Ziergarten	Ornamental garden
Hopfengarten	Hop garden
Weingarten	Vineyard
Weide	Pasture
Weide mit Obstbäume	Pasture with fruit trees
Weide mit Holznut	Pasture with use of wood
Teich	Pond
Nadelhochwald	High coniferous forest
Laubhochwald	High deciduous forest
GemischtHochwald	High mixed forest
Niederwald	Low forest
Gestrippe	Scrub
Steinbruch	Stone quarry
Lehm-, Sand-, Schotter- Gruben	Clay, sand, and gravel quarry
Oedung	Bare land
Flussoder Bach	Water stream
Weg	Road
Vorhof	Courtyard
Haus	House

surrounding objects. If the object had signs of two or more land-uses, all possible land-use classes were registered. We further visually detected the differences in objects' spatial delimitation in the three cartographic sources.

We applied database conditions to find all objects that do not have the same registered land-use in all the four sub-sources. All objects that fulfill this condition were manually checked for interpretation mistakes to find real inconsistencies in the sub-sources. Upon the ex-ante analysis, the following types of content inconsistencies have been identified and further analysed in the whole dataset: 'Not registered', 'Not differentiable', 'Different land-use', and 'Illegible record'. The inconsistencies in spatial delimitation in the three cartographic sub-sources 'Two objects in one', 'Different spatial delimitation' – were analysed visually. The Written registry was considered as a reference source for land-use as it was the basis for tax collection.

We calculated frequency, area and mean area of the inconsistencies. We explored the inconsistencies according to land-use classes and cadastral area. We analysed land-use shifts in some objects among the four data sources via alluvial plots; (Brunson, 2019) to show the relationship between the sources and the limitation of their use. All graphs were created in R (R Core Team, 2018)

3. Results

The six studied cadastral areas contained 5 771 objects, most of which were parcels with numbers. The average size of an object was 0.6 ha, with the exception in the Milovice area, in which the object size averaged 1.4 ha (Table 3).

In four out of six areas arable land had the biggest share (ranging from 31.3% to 66.9% among all cadastral areas), whereas forests (ranging 11.3% to 55.3% among all cadastral areas) covered over 50% of two areas – Babětín and Milešov. Meadows covered a 13.2% share of the Milovice area, and pastures in Koněprusy and Boreč covered 16.3% and 11.7%, respectively.

Table 3. General characteristics of the six studied areas and their land-use structure.

Cadastral area	∑ of objects	Mean object size [ha]	Area [km^2]	arable land [%]	meadows [%]	pastures [%]	permanent cultures [%]	forests [%]	built-up area [%]	other [%]
Babětín	475	0,4	1,9	31,3	4,2	7,7	3,5	50,4	2,0	1,0
Boreč	822	0,5	3,9	66,9	2,2	11,7	3,0	12,2	3,7	0,4
Knínice	1622	0,3	4,4	52,6	7,6	5,9	1,7	28,2	3,5	0,5
Koněprusy	761	0,6	4,4	65,8	1,5	16,3	1,6	11,3	2,9	0,6
Milešov	1255	0,7	8,8	32,8	4,4	3,1	1,4	55,3	2,4	0,7
Milovice	836	1,4	11,8	65,2	13,2	3,1	0,5	14,6	3,1	0,4
Total	5771	0,6	35,1	53,9	7,1	6,3	1,4	27,8	2,9	0,5

Six types of inconsistencies in content and spatial delineation of parcels in the Franziscean cadastre are shown in Table 4. There are 429 objects (in all cases parcels) with a detected inconsistency, out of which 16 objects have two inconsistencies. Meaning around 7.4% of all objects have an inconsistency which comprise 0.3% of the area. The average size of an object with inconsistency is 0.03 ha. Unsurprisingly, objects, which are 'Not registered', have a lesser area than objects with other types of inconsistency (Figure 4), as they are too small to be registered in every data source.

There are several problematic land-uses which often include some inconsistency (high mixed forest, high coniferous forest, pasture with use of wood, vegetable horticulture, a meadow with fruit trees) or in all cases across the study area (e.g., high deciduous forest, scrub, arable land shifting with pasture, scrub and low forest) (Figure 5). Land-uses containing inconsistencies in all cases indicate a systemic error. Also, certain types of inconsistencies are associated with a particular land-use, e.g., 'Different land-use' is typical for all sorts of pastures, while 'Not differentiable' are often by forest land-uses.

Inconsistencies are not equally distributed among the cadastral areas (Figure 6). While in Milovice there are only a few objects with any inconsistency, they occur in about 10% parcels in three other areas (Babětín, Knínice, and Koněprusy). There are typical inconsistencies for some cadastral areas. Three-fourths of incorrectly registered parcels in Koněprusy are noted as 'Not differentiable'. About 40% of wrongly assigned parcels in Knínice fall into the 'Different land-use' category.

We further focus on three types of inconsistencies that cover most of the area: 'Different land-use', 'Not differentiable' and 'Not registered', and explore the differences in land-use of as registered across the four data sources.

3.1. Inconsistency type 'different land-use'

Several land-use classes tend to have 'Different land-use' in at least one data source (Figure 7). Objects drawn as pastures in Compulsory imperial imprints are often evidenced as pastures with fruit trees or pastures with the use of wood in other sources, but there are no inconsistencies at all between the latter two. Agroforestry land-uses, e.g., pastures with any sort of wood (wood-pastures) and arable land with fruit trees are underrepresented in Compulsory imperial imprints. Pastures with

Table 4. Inconsistency types in the Franziscean cadastre.

Inconsistency	Description	Cases ∑
'Not registered'	one object occurring in one source of the cadastre (e.g., Compulsory imperial imprints) is not registered in at least one other source (e.g., Written registry)	79
'Not differentiable'	land-use from one source is not differentiable in other one, i.e. the symbol can mean more than one land-use category	212
'Different land-use'	land-use of the object is not the same in all sources	113
'Illegible record'	land-use of the record in at least one source is not readable	11
'Two objects in one'	object in one source contains two object from other source	2
'Different spatial delimitation'	object in one source has significantly different boundaries in other source	28

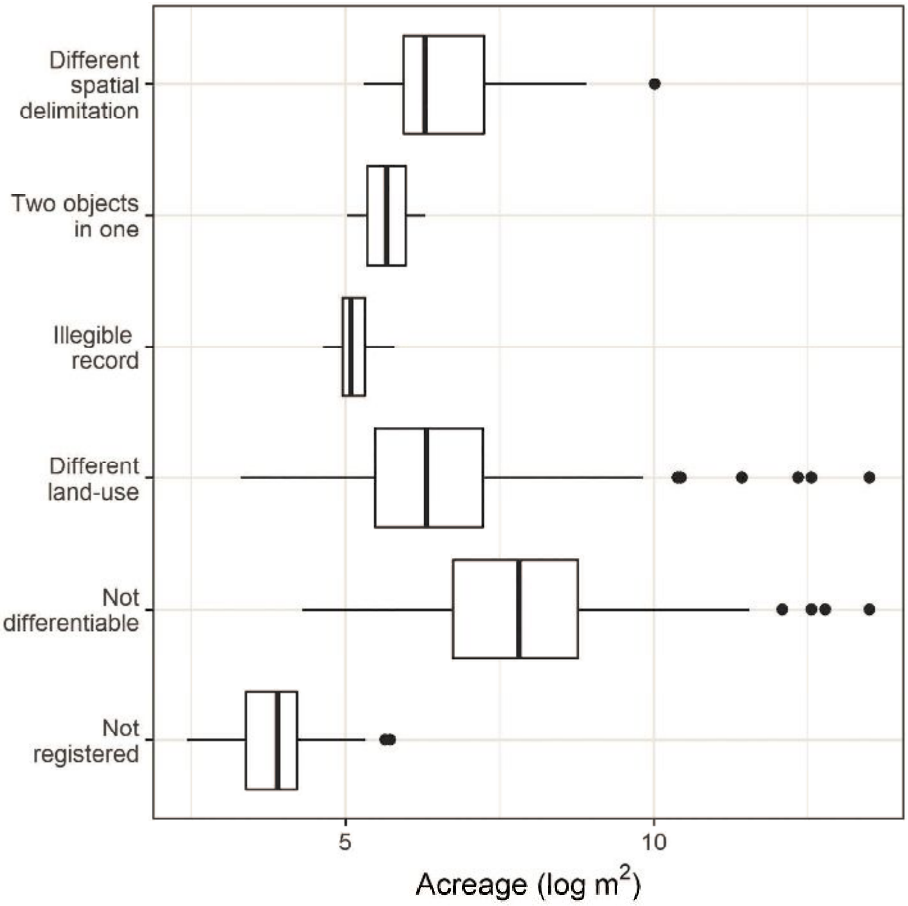

Figure 4. Inconsistency types according to object area.

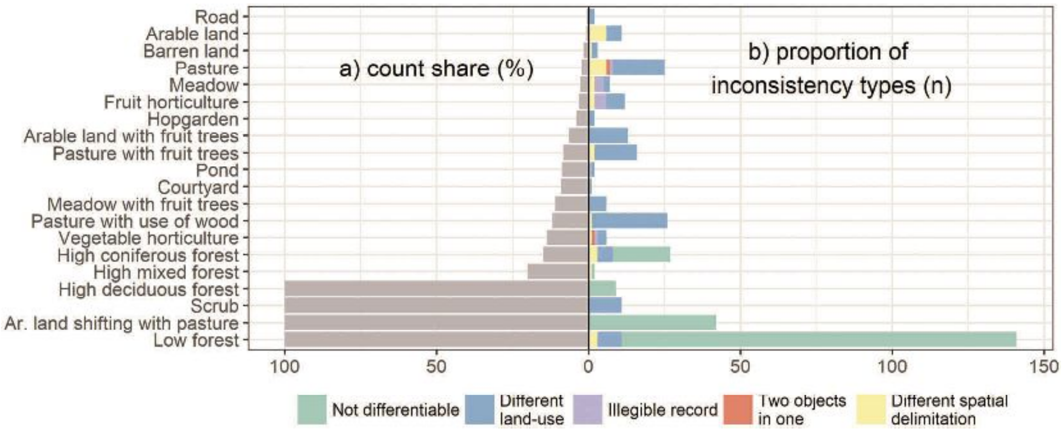

Figure 5. Share of inconsistencies on all parcels of a particular land-use (referential data source: Written registry).

the use of wood in the Written registry and Indication sketches are often registered only as pastures in Original maps.

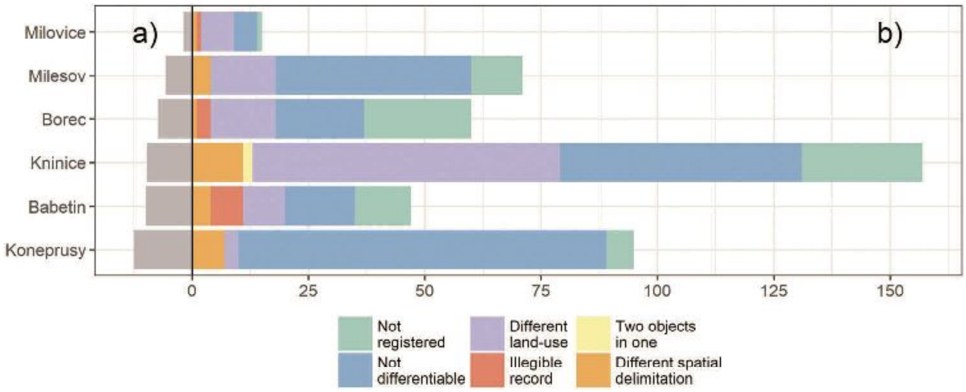

Figure 6. Share of inconsistencies on all parcels in cadastral area expressed in (a) percentage and (b) count with proportion of inconsistency types (one parcel can include one or more inconsistency (parcels with more than one inconsistency = 16).

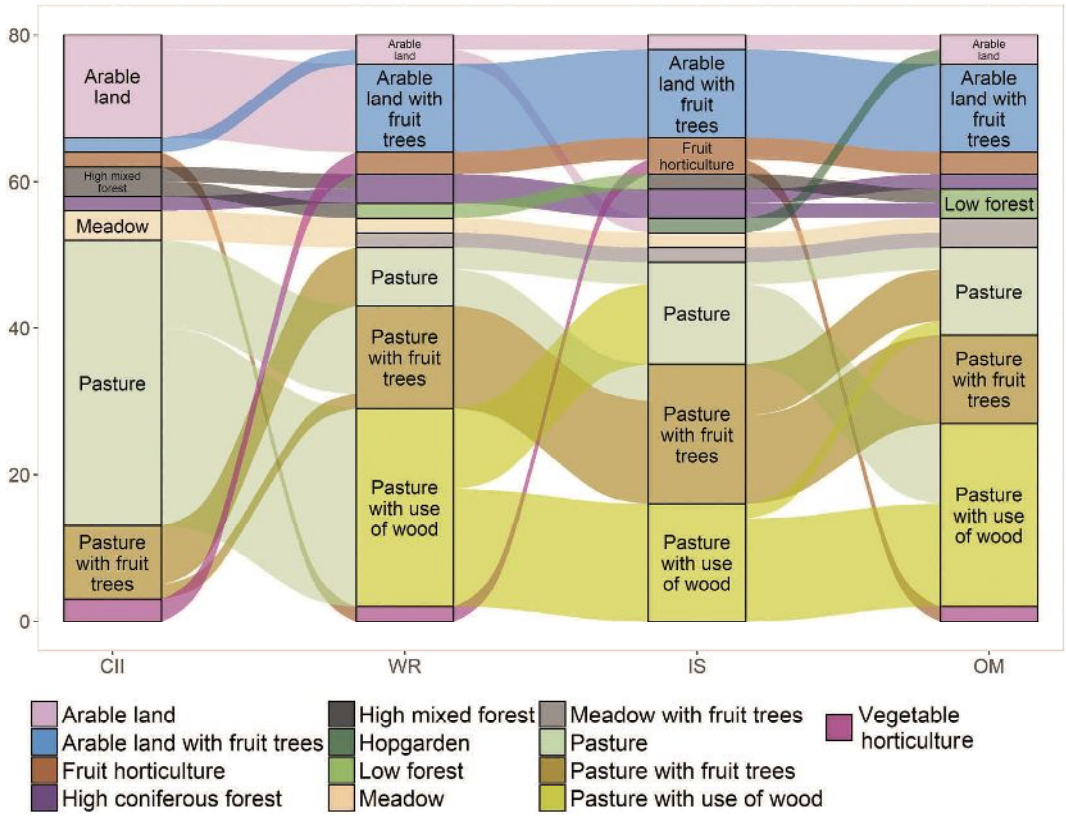

Figure 7. Shifts of land-use in inconsistency type 'Different land-use' among four sub-sources of the Franziscean cadastre. CII – Compulsory imperial imprints, WR – Written registry, IS – Indication sketches, OM – Original maps.

The inconsistency type 'Different land-use' indicates the similarity of the four data sources (Figure 8). The most dissimilar are Compulsory imperial imprints with 86 objects with land-use registered differently from any other data set. Original maps have only 34 objects with uniquely registered land-use. In general, the Written registry and Indication sketches are the most similar data sets differing

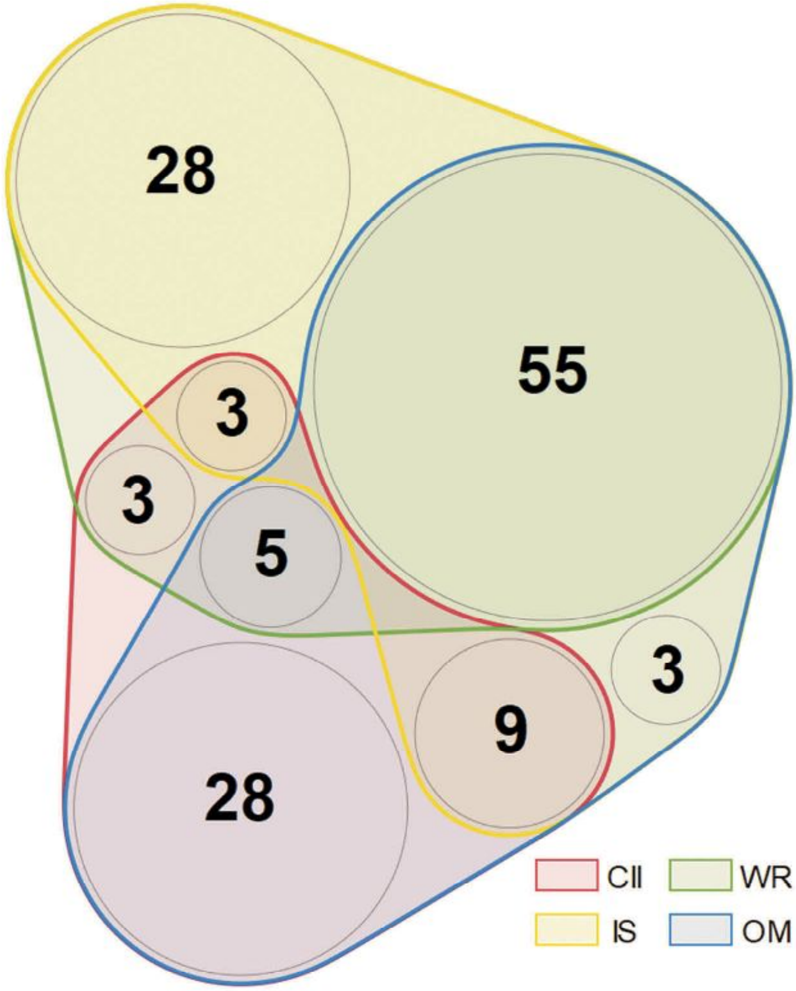

Figure 8. Content dissimilarity in the four data sources. Number in the circle represents number of parcels with a specific similarity of the data sources. Note that no parcel in this case is in all four data sources because the figure is focused on the 'Different land-use' inconsistency.CII – Compulsory imperial imprints, WR – Written registry, IS – Indication sketches, OM – Original maps. Visualised using nVennR package (Quesada, 2018).

only in 20 cases. Original maps stand in the content similarity between Compulsory imperial imprints on one side and the Written registry with Indication sketches on the other.

3.2. Inconsistency type 'not differentiable'

The inconsistency type 'Not differentiable' is mostly a systemic distortion within the data sets of the Franziscean cadastre and is related to two land-use classes, arable land and all types of forests. The arable land shifting with pasture is detectable in Indication sketches (mostly) and the Written registry (always) but is not differentiable from the common arable land in Compulsory imperial imprints and Original maps (Figure 9). The scrub is drawn as a pasture with the use of wood in Compulsory imperial imprints unlike Indication sketches, the Written registry and Original maps. Differentiating forests in the Franziscean cadastre is a problematic task in more sub-sources. The low forests are indistinguishable in Compulsory imperial imprints. Original maps and Indication sketches often do not use enough symbols to differentiate between the forest types (e.g., abbreviation NW can stand

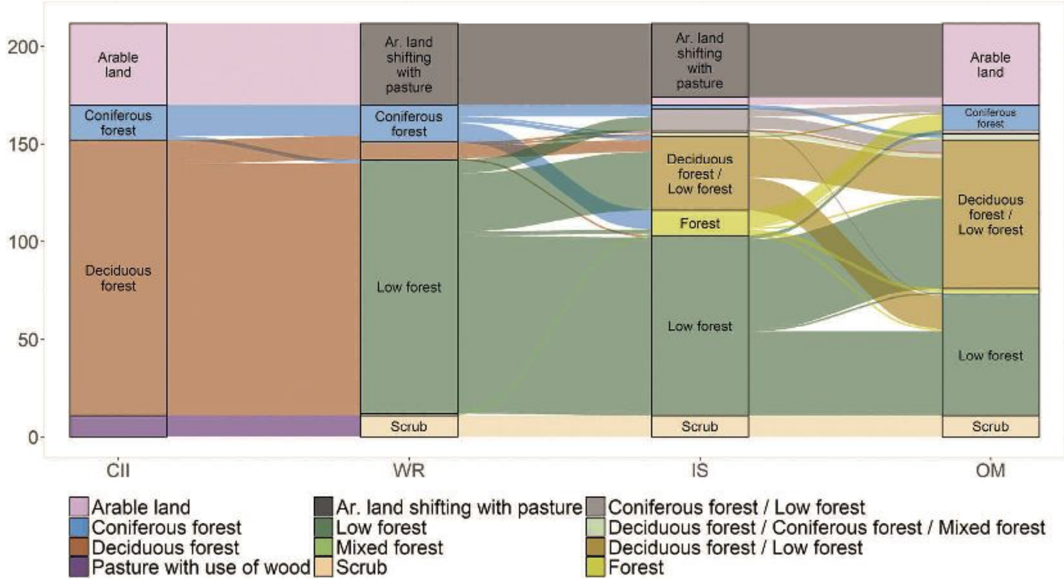

Figure 9. Shifts in land-use within inconsistency type 'Not differentiable' among four sub-sources of the Franziscean cadastre. CII – Compulsory imperial imprints, WR – Written registry, IS – Indication sketches, OM – Original maps.

both for *Nadelwald* (coniferous forest) and *Niederwald* (low forest); a sign of deciduous trees and bushes can mean both low forest and high deciduous forest).

Inconsistency type 'not registered'

Some objects are not registered in certain sub-source (Figure 10). Mostly the data are not registered in the Written registry and in some cases also in Indication sketches. This occurred mostly in the case of small vegetable gardens, pastures and houses. Objects in most cases smaller than 90 m^2, with no parcel number on the map and not registered as a land or construction parcel in the Written registry.

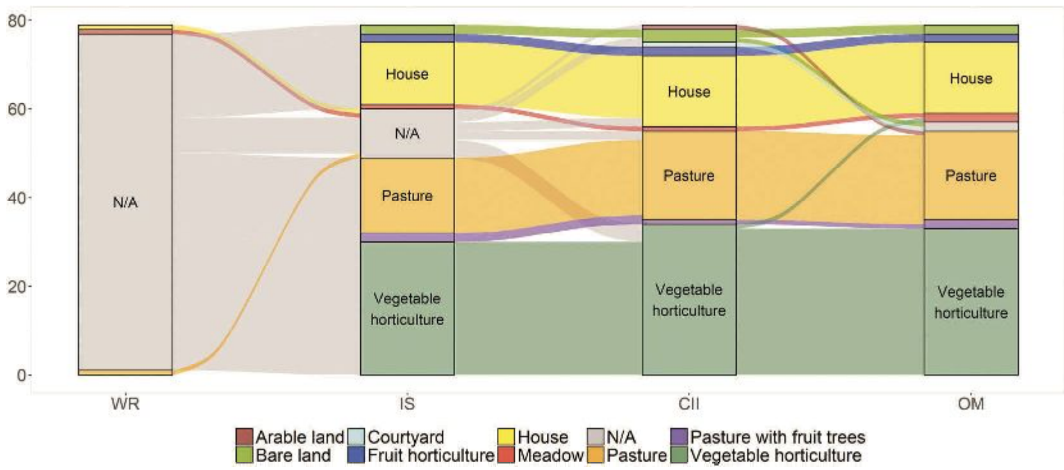

Figure 10. Shifts in land-use within inconsistency type 'Not registered' among four sub-sources of the Franziscean cadastre. WR – Written registry, IS – Indication sketches, CII – Compulsory imperial imprints, OM – Original maps.

4. Discussion

4.1. Extent of inconsistencies

We found four types of content and two types of object spatial delimitation inconsistencies in the Franziscean Cadastre on an example of six cadastral areas. All of the inconsistencies fall into the production-oriented inconsistencies (Leyk et al., 2005), or inconsistencies inherent to historical data, not connected with their digital transformation or use. The inconsistencies concern about 7.4% of all objects and 0.3% of the studied area. Krčmářová (2015), who focused on agroforestry in the middle of the 19th century using the Franziscean Cadastre, compared content of the Written registry with Compulsory imperial imprints in one cadastral area. She found a 99.2% match among the agroforestry land-uses. We found 60 inconsistencies within 678 agroforestry objects in our data set (58 objects with 'Different land-use' inconsistency) which amounts to only 91.2% match. It is probably by the problematic determination of land-use with scattered trees present (Forejt et al., 2018) or the information about the presence of trees was of marginal importance to the surveyors. The presence of trees on a parcel can be a reason for authorities to award the land manager with financial support (Sandberg & Jakobsson, 2018). Another group of land-uses with plenty of inconsistencies is forest (only 168 consistently assigned objects out of 347 with forest land-use, i.e. 48.4%). Specifically, forest types are very often indistinguishable in particular sub-sources. This is a case for low forests in Compulsory imperial imprints. On Original maps or Indication sketches, the drawings and labels give two or more choices for interpretation of the data (vagueness according to Leyk et al. (2005)) which is a cartographic deficit rather than wrongly recorded content.

Additionally, the inconsistencies do not seem to be spatially equally distributed. The survey, drawing and registering was processed in a perfect congruence in some cadastral areas (Milovice and Milešov), while other cadastral areas are very problematic (Knínice, Babětín). This may be caused by each surveyor's precision because the survey was processed in all the cadastral areas by a different worker. Another reason could be the various levels of complexity of ownership and land-use structure or geomorphologic heterogeneity.

4.2. Pros and cons of the sub-sources for land-use reconstructions

In the following paragraphs, we summarize and discuss our main findings to provide an instructive evaluation of the sub-sources' potential for land-use reconstructions. The summary is shown in Table 5.

First, our analysis brings to the users of Compulsory imperial imprints of Franziscean cadastre an important message. While these maps are among the most widely used data sources in landscape structure studies (Dolejš & Forejt, 2019) for their easy readability and accessibility, the information about three land-use types (namely arable land shifting with pastures, low forests, and scrub vegetation) is lost in the data source. Moreover, compared with reference data (Written registry), Compulsory imperial imprints display the highest differences of assigned land-use in comparison to the other map sources. This is especially obvious in the case of the agroforestry land-uses, which are

Table 5. Pros and cons of the sub-sources of the Franziscean cadastre for land-use reconstruction.

Data source	Pros	Cons
Indication sketches	Closest land-use to the Written registry (reference)	Hard to read (much information, change markings), low quality of the image (long used)
Original maps	Easily readable spatial delimitation and land-use	Some land-uses often not differentiable
Compulsory imperial imprints	Easily readable spatial delimitation and land-use	Furthest land-use from Written registry (reference), some land-uses are systemically not differentiated
Written registry	Reliability (taxes were measured according to Written registry), all parcels with explicit land-use	Time demanding, need to have a skill for reading old documents

massively underrepresented in Compulsory imperial imprints, although they have been used for studying agroforestry (Forejt et al., 2017; Vojta & Drhovská, 2012).

In contrast, the similarity of the Written registry and Indication sketches is high, as they were probably used to set the data into the Written registry, which was further applied for tax purposes (Ebel, 2004). On the other hand, the map sheets of Indication sketches must be read and interpreted carefully, as they contain markings of new objects, changes in parcels delineation, and land-use changes made after publication of the cadastre. Such informational abundance may complicate reading and result in an incorrect detection of land-uses.

Since the owners paid the taxes according to what was in the written documents and not maps, the Written registry of the Franziscean cadastre may be considered closest to the reality or at least to its representation as negotiated among stakeholders (owners, surveyors, mayors). Despite this fact, the Written registry has been scarcely used in landscape research (with exceptional studies by Szabó (2010) and Krčmářová and Jeleček (2017)). Work with old written sources on landscape available in archives is demanding on time and skills. If the researcher argues it not worthwhile, he must be aware of the sources' limits.

4.3. Limits to the empirical evidence

We included in our research the inconsistencies 'Two objects in one' (object in one source contains two objects from the other source) and 'Different spatial delimitation' (object in one source has significantly different boundaries in the other source) describing mistakes in objects spatial characteristics. This was done only using visual evaluation of similarity to Compulsory imperial imprints. A more precise method would be to digitize other map sources, i.e. Original maps and Indication sketches. This task would demand specific adjustments in georeferencing for each map source and development of a computational method for assessing the rate when the delimitated parcel boundaries already significantly differ and when an object already includes two objects from the other source.

Finally, it must be reiterated that our findings are based only on six cadastral areas localized in one country of the former Austrian Empire (only in Czechia, there were more than 13 000 cadastral areas; Bičík et al., 2001). A different spatial setting may display other land-uses and various rates of inconsistencies. Moreover, the interpretation of the results and comparisons across the land-use categories must be made carefully as some land-use categories are only scarcely represented within the dataset. Although the sample cannot be regarded as statistically significant and the case study does not reflect the variability of natural conditions of all the regions covered by this old cadastral apparatus, the findings provide new insight in the apparatus complexity and informational quality. In particular, the found inconsistencies and their quantitative evaluation provide the empirical base for other studies exploring the possible effects of the use of old cadastral maps on the accuracy and suitability of land management interventions (e.g., land-use structure or habitat connectivity designs for restored landscapes).

5. Conclusion

The presented study analysed inconsistencies in the old cadastral sources using the example of the Franziscean cadastre from the 19th century, which covers the major part of Central Europe and is among the most frequent sources for historical land-use reconstructions. The study is based on spatial and content comparison of four sub-sources of the cadastral apparatus. According to our research, the six identified inconsistencies comprise about 7.4% of all parcels with agroforestry and forestry land-use categories being especially prone to these inconsistencies. Based on these findings we provide an instructive summary of the potential and limits of the individual sub-sources of the Franziscean cadastre for historical land-use reconstructions. While most studies in geography, landscape ecology and history generally admit uncertainties in archival sources, the present empirical evidence provides an idea of the specific uncertainties emerging from data inconsistency and their extent. To fully understand the uncertainties in land-use reconstructions resulting from data inconsistency, we call for further evidence obtained from other old cadastral sources located in other regional settings.

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4. Changes and continuity of wood-pastures in the lowland landscape in Czechia

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Changes and continuity of wood-pastures in the lowland landscape in Czechia

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ABSTRACT

The term wood-pastures is usually applied to areas with trees or other woody vegetation, scattered through a mainly grazed grassland area, and reflects one of the oldest land use types in Europe, which plays important ecological, agricultural and socio-cultural roles. However, a rapid decline in their area due to changes in land use and a lack of tree regeneration has recently been observed all over Europe, which has led to the necessity of a deeper understanding of their behaviour in relation to different factors via a detailed analysis of the history of the changes in their distribution over space and time. Despite the recent increase in the number of related studies, information on historic patterns of wood-pastures in many European locations, such as Czechia, remains incomplete. The goal of this study is to assess the habitat continuity of current wood-pastures and to analyse the land-use/land-cover changes of historical and current wood-pastures in lowlands and warm landscapes of hills and basins of Czechia. To achieve this, nine sites covering a total area of 98.6 km^2 were studied in Czechia. The situation on three time horizons (1820–1840s, the early 1950s and today) was analysed. The results have shown that almost all wood-pastures from the 1st half of the 19th century have now been lost and most of the currently existing ones were formed from the 1950s till today. Most wood-pastures, which were lost by the 1950s, were turned into open habitats, such as arable lands, and the ones lost from 1950 were turned into forest. New wood-pastures are mostly formed from open habitats, often in former military areas.

1. Introduction

Wood-pastures, grazed grasslands with scattered trees or shrubs, are threatened landscape features all over Europe. This is perceived as a negative tendency because wood-pastures are increasingly being recognized for their great ecological, cultural and agricultural importance (Hartel & Plieninger, 2014). The ecological value expressed is given by great structural diversity (Garbarino & Bergmeier, 2014; Jakobsson & Lindborg, 2015), extensive but multiple land use (Opperman, 2014), and the presence of trees serving as keystone structures (Manning, Fischer, & Lindenmayer, 2006). Specifically, old trees are typical for wood-pastures in Britain (Butler, 2014; Read, 2000) and in Romania (Hartel et al., 2013; Moga et al., 2016). Economic use of wood-pastures can be varied. In Europe, trees and grassland in wood-pastures have traditionally served as a source of fodder for grazing animals, the trees also for timber or fuelwood and their crop for pannage (Szabó & Hédl, 2013; Szabó, 2013). Traditional management methods include hay making, berry and fruit picking, which is typical for Germany (Bergmeier, Petermann, & Schröder, 2010; Hartel, Plieninger, & Varga, 2015). Nowadays, the aim is to build new links between wood-pastures and people (Hartel & Plieninger, 2014). Cultural value is explained mainly as the tradition that wood-pastures represent, which is perceived by farmers in Estonia (Roellig et al., 2015) and in Romania (Sutcliffe, Öllerer, & Roellig, 2014). The potential of wood-pasture landscapes for regional development was understood in whole communities in the Black Forest in Germany (Bieling & Konold, 2014). As an example of the value of wood-pastures from the point of view of aesthetical perception, farmers and common inhabitants in the Alentejo region

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in Portugal appreciate complex landscapes, such as the Portuguese type of wood-pasture, *montado,* for their visual qualiies. (Surová, Pinto-Correia, & Marušák, 2014).

We can state that people start to be somewhat aware of the importance of landscapes as soon as they start to be threatened (Antrop, 2005). Bergmeier and Roellig (2014) name as some of the most important threats to wood-pastures the decline of old trees, lack of trees regeneration (Kirby, 2015), overgrowing by woody vegetation, and land-use intensification by transforming a wood-pasture into either a pasture without trees or into different land use. Conversely, Roellig et al. (2015) refer to wood-pastures restoration in Estonia. Van Uytvanck, Maes, Vandenhaute, and Hoffmann (2008) talk about wood-pastures formation on former arable land and grassland in Belgium. Our study deals with land-use and land-cover change (LUCC), describing the processes of persistence, extensification and intensification in the case of past wood-pastures on the one hand, and the formation of new ones on the other.

In recent decades, the number of studies monitoring changes in the landscape have increased, especially accelerated by the emergence of geographic information system (GIS) (Cousins, 2001; Echeverría, Newton, Nahuelhual, Coomes, & Rey-Benayas, 2012; Ihse, 1995; Kienast, 1993; Pino et al., 2010; Munteanu et al., 2014; Plieninger, 2012). The ability to more easily monitor the land use/ cover changes (further referred to as LULC) has played a key role (Turner, Lambin, & Reenberg, 2007). There are also many relevant studies focusing on the analysis of spatial changes in the landscape (Khromykh & Khromykh, 2014; Boltižiar, 2001; Hreško & Boltižiar, 2001; Hreško, Boltižiar, & Bugár, 2003; Olah, Boltižiar, & Petrovič, 2006; Seabrook, McAlpine, & Fensham, 2007; Spanò & Pellegrino, 2013). It is especially important is to study landscape persistence (Bürgi, Hersperger, & Schneeberger, 2004).

In relation to pastures, Pătru-Stupariu, Tudor, Stupariu, Buttler, and Peringer (2016) used old maps to study the persistence of pastures, forests and built-up areas in Romania's Carpathians in the periods between 1912, 1980 and 2009. From the studied temporal horizons, the highest proportion of pastures existed in 1980. Pastures showed higher persistence than forests and built-up areas. In reflect of the situation in Czechia, Bičík, Jeleček, and Štěpánek (2001) analysed cadastral evidence from 1845 to 2000. Of all the analysed classes of land use, the sharpest decline between 1845 and 1948 was seen in grasslands. On the other hand, an increase in the share of the same class between 1990 and 1999 was again sharpest in grasslands in comparison to other categories.

Change trajectories of non-forest woody vegetation, which is another topic closely linked to wood-pastures, was analysed by Plieninger, Schleyer, Mantel, and Hostert (2012), who described the spatial-temporal dynamics of trees outside forest in Eastern Germany in the period 1964–2008, which showed a positive net change during the socialist and post-socialist period. Scattered fruit trees were the only declining type of non-forest woody vegetation. Demková and Lipský (2015) described a decline in non-forest woody vegetation in Eastern Czechia during the socialist period and its expansion during the post-socialist period.

It is important to study LUCC and the persistency of wood-pastures to learn about the threats influencing wood-pastures and the drivers underlying the ancient ones. So far, LUCC in silvopastoral landscapes has been studied intensively, especially in Iberian Peninsula. The results showed a decline in *montado* and *dehesa* area in the 2nd half of the 20th century (reviewed by Costa, Madeira, Santos, & Plieninger, 2014). If we take into consideration land persistence, in a case study of two areas in south-western Spain, 78% and 89% of the initial wood-pasture area remained persistent between 1956 and 1998. Here, shrub encroachment was the most common cause of losses. The gains occurred in most cases on former grasslands and shrublands (Plieninger, 2006). In southern Portugal, 41%, 42% and 81% of the wood-pasture area respectively in three different areas proved to be persistent between 1958 and 2007 (Costa, Madeira, Lima Santos, & Oliveira, 2011). In Northern Lesvos in Greece, 90% and 55% of wood-pastures in two areas respectively were persistent between 1960 and 2010 (Schaich, Kizos, Schneider, & Plieninger, 2015). In southern Germany, 78% of orchard meadows (regardless of whether grazed or not) between 1968 and 2009 were persistent (Plieninger et al., 2015b). A totally different situation was observed in the case of the Italian Alps, where between 1961 and 2003 there was only 16% and 5% persistence in wood-pasture area in two study areas, respectively, which were defined here by 10–30% tree canopy cover. The wood-pastures were typically transformed into forests (Garbarino, Lingua, Subirà, & Motta, 2011). Varga, Ódor, Molnár, and Bölöni (2015) give evidence about wood-pasture formation in the 19th century in Hungary and their extinction in the post-socialist era. This is the only study focusing explicitly on wood-pasture landscape dynamics in East-Central and Eastern Europe which we found.

As for Czechia, we know that wood-pastures covered about 1.6% of the whole area of the country in the 1st half of the 19th century (Krčmářová & Jeleček, 2016) when the general trend of separation of forest and agricultural use on one piece of land was occurring (Jørgensen & Quelch, 2014). According to the point database LUCAS, 1.1% of Czechia in 2012 was covered by wood-pastures (Plieninger et al., 2015a), although it was believed that silvopastoral systems virtually did not exist there (Hartel et al., 2015). Little is known about the history of these habitats or whether there are some potentially ancient wood-pastures. In the current study, which is focused on wood-pastures in lower parts of Czechia, we try to answer the following questions:

1. How long is the continuity of wood-pastures?
2. What are the sinks of wood-pastures from the past?
3. What are the sources of current wood-pastures?

We will answer the questions by analysing change trajectories in GIS using land use maps from the 1st half of the 19th century, orthophotos from the 1950s and 2013/4 complemented by field mapping.

2. Methods

2.1. Study area

The geographical framework of the study is represented by the regionalisation of Romportl, Chuman, and Lipský (2013). The regionalisation combines climatic and geomorphologic characteristics, namely average annual temperature, slope and elevation, and constructs six regions, called “general types of natural landscapes”. We chose the two mildest of them – warm lowland landscapes and moderately warm landscapes of hills and basins. These two types cover 46.6% of Czechia and are generally characterized by a high population density (71% of inhabitants of Czechia) (ČSÚ, 2011), a low cover of forests (20.4%, while 33.3% in all Czechia) and a high cover of agricultural land (67.7%, while 57% in all Czechia) in comparison to the whole country (CENIA., 2014).

Within these two climatic-geomorphic regions we analysed nine historical cadastral districts (Fig. 1). We took the historical cadastral district as the sampling unit because of the consistency and accessibility of data on historical land use. The boundaries of current cadastral districts might differ from the historical ones. To include a district in the analysis, we set a threshold that at least 0.5% of the district's current land cover must be occupied by wood-pasture land use. We applied this condition and did not use any kind of random sampling as it is generally believed that wood-pastures virtually do not exist in Czechia today (Hartel et al., 2015) and for the aims of our study, it would be useless to consider districts with no wood-pasture. For this reason we used orthophotos (ČÚZK, 2016) to identify suitable areas in various parts of warm and moderately warm landscapes of Czechia where there are patches with scattered trees. Only nine districts were included in the presented analysis, even though we actually verified more districts. The area of separate districts ranges from 3.8 to 28.6 km^2. In total, they cover 98.6 km^2, which represents 0.3% of warm lowland landscapes and moderately warm landscapes of hills and basins in Czechia (Table 1). The studied districts are covered by arable land (45.8 ± 20% = mean ± SE), forests (23.3 ± 16.7%), heterogeneous agricultural areas (12 ± 7.8%) and grasslands (6.7 ± 11%) according to the CORINE land cover database from the year 2012 (CENIA., 2014).

2.2. Data sources

We analysed three temporal horizons using different types of data sources, including old maps, aerial images and orthoimages:

2.2.1. 1st half of the 19th century

The period we are focused on starts with the 1st half of the 19th century because it is the first temporal horizon available with relatively exact map evidence on the extent of wood-pastures in Czechia. We base our analysis on a series of Stable Cadastre maps, covering the whole former Habsburg monarchy; these are widely used to study Land Use Land Cover in Czechia (e.g., Bičík et al., 2001; Lipský, 1995; Raška, Zábranský, Brázdil, & Lamková, 2016). Different parts of Czechia were mapped from 1824 till 1843 and the studied cadastral districts cover different map sheets which were mapped throughout this long period. Due to this we use the dating "1st half of the 19th century" in this paper. Besides ordinary land-use classes, the Stable Cadastre also records those which might be considered agroforestry (Krčmářová & Ječek, 2016), including pastures, meadows and arable land with various types of trees. We used the so-called Imperial imprints of the Stable Cadastre, which are large scale maps (1:2880). We obtained the Imperial imprints as scanned images from the Czech Office of Surveying Mapping and Cadastre (ČÚZK, 2015) and georeferenced each map sheet in ArcGIS software (ESRI., 2015) to control points identified on the current cadastral map to distinct corners of parcel boundaries or parcel intersections that we considered not to have changed their shape. The total number of map sheets was 71. For 62 of them, 1st order polynomial transformation was used, where the root mean square error (RMSE) was on average 1.4 per map sheet. The rest of the map sheets were transformed by 2nd order polynomial transformation, where RMSE was on average 1.6 per map sheet. The transformation method was chosen to best fit the current cadastral map.

2.2.2. 1953/54

The temporal horizon of the 1950s was chosen as it represents one of the most important breakpoints in Czech cultural landscape history. After this period, huge and systematic changes in the landscape were accomplished, when consolidation of land parcels took place as a means of agricultural intensification. One of the outputs was the abandonment of distant and less productive land. (Lipský, 1995). To capture the landscape composition of this period, historic black-and-white orthophotos from 1953/1954 were used (CENIA., 2012). From these orthophotos we were able to distinguish only land cover as no reliable data source on land use from this period in Czechia is available. For this reason, we did not distinguish the land use class "wood-pasture", only semi-open habitats. Some studies use historical aerial images to distinguish wood-pastures, but it is suitable only in areas where wood-pastures are common and traditional land management is present (Costa et al., 2014; Plieninger, 2006; Schaich et al., 2015). The 1953/1954 period serves us as an indicator of the dynamics and age of woody vegetation, but not of the land use.

2.2.3. 2015/2016

To determine current LULC, we used complementary data sources. The orthophoto was taken as the basis and was supplemented by LPIS (Land Parcel Identification System) to distinguish agricultural land (MZeČR, 2016). As another source a layer of land, treated as a forest, was used (ÚHUL, 2000). The areas where we expected wood-pastures to be found were verified directly in the field in July and August 2015 and then reviewed in October and November 2016.

Because of the variability of types of data sources, we used five categories of LULC based mainly on tree density and tree canopy cover, which was interpreted visually as follows:

- Open habitats with less than 7 trees/ha. For the 1st half of the 19th century, only those parcels depicted as agricultural with no woody vegetation.
- Semi-open habitats with at least 7 trees/ha and maximally 80% tree canopy cover. The threshold was inspired by other studies on sparse woody vegetation development (Garbarino et al., 2011; Grossmann & Mladenoff, 2007). For the 1st half of the 19th century, all parcels with agricultural land use with woody vegetation as subordinate land use.
- Wood-pastures as a subtype of semi-open habitats where grazing is the dominant management of semi-open grassland. These could be identified for the 1st half of the 19th century as pastures with trees and for 2015/2016, but not for the 1950s (for the reasons, see above).
- Closed habitats with at least 80% tree canopy cover. In this class we also include all land evidenced as forest by ÚHUL (2000), although these may be temporarily open but we cannot expect any pastoral management because grazing by domestic animals has been prohibited since 1960 (NSČSSR, 1960) and not practised now. We include in this class all forest parcels of the Stable Cadastre although we cannot know what the actual tree canopy cover on the parcels was.
- Other areas including urban and industrial areas and water streams and bodies.

2.3. Data processing and analysis

On the basis of previously mentioned data sources, we vectorised all wood-pastures in the 1st half of the 19th century and in 2015/2016 in the ArcGIS 10.4 environment (ESRI., 2015). The minimal mapping unit was set to 0.3 ha. We interpreted LULC of current wood-pastures in 1953/1954 and in the 1st half of the 19th century. At the same time, we interpreted LULC of wood-pastures from the 1st half of the 19th century in 1953/54 and in 2015/2016. We did not vectorise all study areas, only areas where wood-pastures exist or existed, similarly to studies on non-forest woody vegetation (Demková & Lipský, 2015; Plieninger et al., 2012).

We performed an overlay analysis using the *Intersect* and *Union* tools. The final layer was transformed into raster using the *Feature to raster* tool to eliminate sliver polygons (Grossmann & Mladenoff, 2007). The raster cell size was set to 5 m and the value was controlled by the value of the largest area in the cell. All wood-pastures were then classified according to their continuity into the following groups: continuous, lost by 1950s, lost by 2015/2016, gained by 1950s, and gained by 2015/2016. We also analysed sinks of lost wood-pastures and sources of current ones.

3. Results

3.1. Overall changes

The total area of wood-pastures in the study area was 163.7 ha in 2015/2016, which makes up 1.7% of the studied districts, as against 78.1 ha in the 1st half of the 19th century, meaning 0.8% of the studied area (Table 1). This is more than twice as much. On the other hand, there are big differences between the districts, e.g., the Milovice district (ID 6 in the Fig. 1) has a large wood pasture now, while there was no large one in the 1st half of the 19th century. On the other hand, in the Bohdalice district (ID 1) there was a decline in wood-pastures of 77%.

3.2. Habitat continuity

Looking at wood-pastures evidenced in the 1st half of the 19th century, one can see that already by the beginning of the socialist era more than half of their area had been lost. 44.1% of wood-pastures area was lost during the second period (Fig. 2). Only 1.9% of those wood-pastures that existed in the 19th century were present on all three horizons. There are two larger patches of continuous wood-pastures, namely in the Rovné and Mšec districts (ID 8 and 7, respectively). When we consider the current situation,

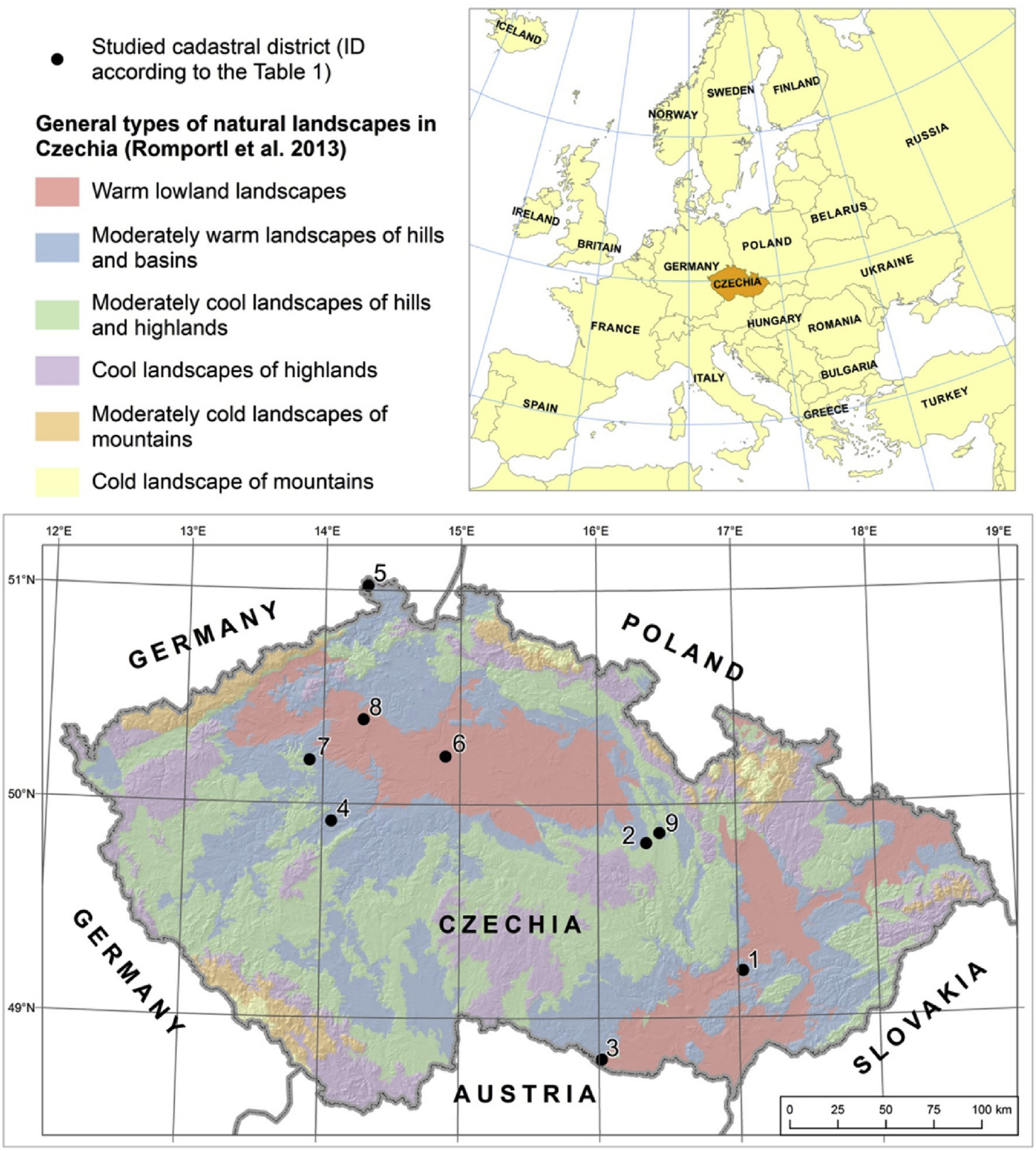

Fig. 1. Localisation of the 9 studied cadastral districts with the context of the general types of natural landscapes in Czechia (Romportl et al., 2013). The number of a district refers to the Table 1.

Table 1
Overall changes of wood-pastures cover in the studied areas between the 1st half of the19th century and 2015/2016.

ID	District	Area (km^2)	Wood-pastures 1824–1843		Wood-pastures 2015		Net change	
			ha	% of district area	ha	% of district area	ha	% of initial area
1	Bohdalice	5,0	12,8	2,6	2,9	0,6	−9,8	−77,0
2	Čistá	28,6	14,4	0,5	30,5	1,1	16,1	111,9
3	Havraníky	11,3	23,2	2,0	28,7	2,5	5,5	23,9
4	Koněprusy	4,4	1,8	0,4	19,4	4,4	17,6	980,9
5	Lobendava	11,4	4,9	0,4	18,3	1,6	13,4	271,7
6	Milovice	11,8	1,8	0,2	37,5	3,2	35,6	1932,2
7	Mšec	13,8	15,8	1,1	7,4	0,5	−8,4	−53,2
8	Rovné	3,8	1,8	0,5	4,3	1,1	2,5	136,3
9	Semanín	8,6	1,7	0,2	14,8	1,7	13,1	792,7
Total		98,6	78,1	0,8	163,7	1,7	85,6	109,6

more than four-fifths of the wood-pastures in 2015/2016 emerged at a certain time during the last 60 years.

3.3. Sinks of wood-pastures from the past

When we have a look at sinks for wood-pastures lost by 1953/1954 (for an example of such trajectory see the Fig. 5B), most of their area was transformed into land uses with no trees, meaning arable land or grasslands (Fig. 3). Some of these overgrew back in the second period with trees to become semi-open or closed. There are some cases where they were open in 1953/1954 and became wood-pastures again by 2015/2016. Characteristically almost all semi-open areas from 1953/1954 which could have still been wood-pastures at that time had become forests by 2015/2016. Surprisingly, only a small portion of former wood-pastures were transformed into other categories, such as urban areas.

3.4. Sources of current wood-pastures

Concerning wood-pastures present in 2015/2016, the vast majority of them are formed on areas which had been overgrown by woody vegetation during the last 60 years (Figs. 4 and 5A). We can expect the trees there to be very young. An example of such change trajectory is the case of the former military training area in the Milovice and Semanín districts (ID 6 and 9, respectively), where valuable grasslands which are being conserved by grazing have evolved. In fact, 58% of the wood-pasture area is grazed as a management tool of grasslands with high biodiversity, either in state nature reserves or private nature reserves. Almost none of the current wood-pastures have formed in places which were occupied by forests in the 19th century, and in those where wood-pastures do exist, the forest was converted before 1953/1954. If we consider semi-open habitat continuity, only 3.8% (6.3 ha) of the current wood-pasture area has performed such continuity during the last 170 years. An example of such development is a wood-pasture in the Rovné district (ID 8) formed on a historical parcel of arable land with fruit trees.

4. Discussion

4.1. Discussion on results

The increase in the area of wood-pastures is related to the fact that we did not locate case study sites randomly in lowland and warm landscapes of hills and basins in Czechia, but situated them purposely in sites where wood-pastures are present so that we can record the change trait of wood-pastures in time. However, that does not mean that since the 1st half of the 19th century the overall area of wood-pastures in lowlands in Czechia increased by more than 100% as in our case study (Krčmářová & Jeleček, 2016; Plieninger et al., 2015a). On the other hand, most of the case studies that analysed historical changes and causes in wood-pastures in Europe generally documented a decrease in the extent of wood-pastures, respecting different natural and cultural conditions (Costa et al., 2011; Garbarino et al., 2011; Plieninger, 2006; Schaich et al., 2015; Varga et al., 2015).

Although we report a positive net change in the overall area covering silvopastoral patches, almost none of the current wood-pastures have had habitat continuity throughout the whole period and only a small portion have had continuity for the last 60 years. This contrast with the studies from Spain (Plieninger, 2006), Portugal (Costa et al., 2011), Germany in case of orchard meadows (Plieninger et al., 2015b) and Lesvos (Schaich et al., 2015), although all of those papers describe much shorter time periods. Only in the Italian Alps was the persistence of wood-pastures similarly low (Garbarino et al., 2011).

We can only speculate about the consequences of wood-pasture dynamics for biodiversity. Ancient wood-pastures are generally considered important biodiversity hot-spots (Falk, 2014; Paltto, Nordberg, Nordén, & Snäll, 2011). Therefore, the losses of wood-pastures with potentially old trees that were documented in our study could be responsible for significant diversity losses in the past at both the local and regional level. However, precise quantification of the losses might be difficult if not impossible. We should consider the possibility that many species could have found alternative habitats in the grasslands and forests which replaced the original wood-pastures. At the same time, newly established wood-pastures would probably mean diversity gains in the landscape. Open grazed shrublands are often richer in species than other habitats, as seen in some examples from Romania (Vojta, Kovář, & Volařík, 2014), regardless of the presence of old trees. Shrubs on a pasture are important for specific bird species (Hartel et al., 2014). A case study from the East Vättern scarp landscape in Sweden shows that γ- and β-diversity in wood-pastures increases along the gradient of tree density on a pasture (Jakobsson & Lindborg, 2015).

Concerning the fate of wood-pastures depicted in the Stable Cadastre from the 1st half of the 19th century, slightly fewer than half of them persisted until at least the 1950s. The former semi-open wood-pastures have turned more into open habitats (be they arable land, meadow or pasture without trees) than into closed canopy habitats, which indicates intensification of agriculture in the period. This could have happened already at the end of the 19th century when a large loss of pasture area and gains in arable land occurred in Czechia (Bičík et al., 2001). The period 1840s–1950s was characterized by a blossoming of private peasant agriculture with a high share of people and working animals. Moreover, new technical equipment and new plants allowed the use of less productive land for more intensive agriculture (Grešlová

Kušková, 2013; Jepsen et al., 2015; Šantrůčková, Dostálek, & Demková, 2015). Our case study reflects a process different from one site in the Bakony hills in Hungary, where a wood-pasture was formed between 1818 and 1880 on the site of a former forest (Varga et al., 2015). On one site in the Romanian Carpathians, large gains in forests in the period 1790–1867 took place at the expense of pastures, which also shows a development different from that reported in the current paper (Pătru-Stupariu, Angelstam, Elbakidze, Huzui, & Andersson, 2013).

Almost all of the wood-pastures from the 1st half of the 19th century in the area of the current study, which remained semi-open until the 1950s, changed into forest land in the second period. This indicates that after the 1950s these areas were subject to more extensive land use. Agriculture after the 1950s was characterized by collectivization, large open fields, and heavy mechanization. On the other hand, less accessible and arable lands were abandoned or reforested (Grešlová Kušková, 2013; Jepsen et al., 2015). The authors studying wood-pasture dynamics in the 2nd half of the 20th century referred to broadly agree in identifying the driving forces which had a major impact towards the decline or to a lesser extent, the emergence of recent wood-pastures. Both suggest a process of intensification and especially intensive grazing (Plieninger, 2006; Schaich et al., 2015; Varga et al., 2015) resulting in the loss of wood-pastures. They also document opposed processes of farming extensification and abandonment, both resulting in tree and shrub encroachment (Plieninger, 2006) which together with the depopulation as well as the abandoning of traditional management techniques play a great role behind the decline in wood-pastures.

Current wood-pastures in lowlands and hilly landscapes in Czechia are have nearly all recently formed on former open habitats. This phenomenon is consistent with the process of abandoning less accessible land in the communist era in Czechia described above (Bičík et al., 2001) and agricultural extensification in the 1990s (Feranec, Jaffrain, Soukup, & Hazeu, 2010). On the other hand, there is a potential to restore wood-pastures (Roellig et al., 2015) from overgrown ones which were converted into closed canopy habitats in case these patches are not registered as forest land in the Czech cadastre. On former agroforestry patches old trees can still be found today (Krčmářová, 2016).

Talking of spatial-temporal changes of wood-pastures in the study sites, they represent rather dynamic landscapes in comparison to the more persistent wood-pasture landscapes of Spain, Portugal and Lesvos. Moreover, in the lowlands and hills in Czechia wood-pastures are not a traditional land use (Krčmářová & Jeleček, 2016). Ironically, land use of wood-pastures, which has a long tradition in Europe (Jørgensen & Quelch, 2014), might be considered allochthonous here. In other words, even though these landscapes did not exist in the past here (Antrop, 2005), we can celebrate them as sustainable landscapes of the future and as an example of integrated landscape management (Manning et al., 2006). However, their sustainability should be further studied especially by means of a land-users' motivation analysis.

4.2. Discussion on the methodology

This study was conducted as a case study, as it was based on 9 specific cadastral districts (sample plots) in warm lowlands and moderately warm landscapes of hills and basins in Czechia (Romportl et al., 2013). The studied area covers 98.6 km^2, which is about 0.3% of all the lower located parts of the country. We selected such districts where wood-pastures cover at least 0.5% of the district's area. Thus, the results are not generalizable in terms of changes in the extent of wood-pastures today and in past but they report about the continuity of current wood-pastures.

In contrast to the current study, most of the other related studies have applied a shorter time perspective, using historical aerial photographs. Thus, Garbarino et al. (2011) documented the loss of wood-pastures in the central part of the Italian Alps in one time period between 1961 and 2003, Schaich et al. (2015) looked at a similar period in Greece on Lesvos island (1961–2010), and Plieninger (2006) made a multitemporal analysis of the development of wood-pastures with three temporal horizons (1956 - 1984–1998) at locations on the Iberian Peninsula. A much longer period was analysed by Varga et al. (2015) in hilly areas in Hungary (1818–2005) in four periods, and in addition to aerial photographs old maps were used.

It is essential to note the specific limits and assets of the different data sources that were used for the studied time horizons (Table 2). The method proposed here may be applied to the entire area which was involved in the Stable Cadastre mapping, which includes most of the former Habsburg Empire. The obstacles in georeferencing and digitising old maps were eliminated by transforming the vector layer into a raster with a 5-m cell size. Old maps of the Stable Cadastre are a solid data source but have their limits as we cannot judge the land cover from them. The threshold defining wood-pastures according to their tree density in the presented study is thus only to a certain limit comparable with the patches defined as pastures with trees or shrubs in the Stable Cadastre.

Aerial photographs, as another data source we used, usually give more precise and detailed information (Herold, Goldstein, & Clarke, 2003) but they do not reflect land use, and sometimes land cover, especially for the 1950s, due to their lower quality. Thus, we are limited in information upon land use for the 1950s time horizon, while for 2015 we are able to get enough related information from additional sources. In historic aerial photos from the 1950s, only the category covering all semi-open habitats could be used. Grasslands

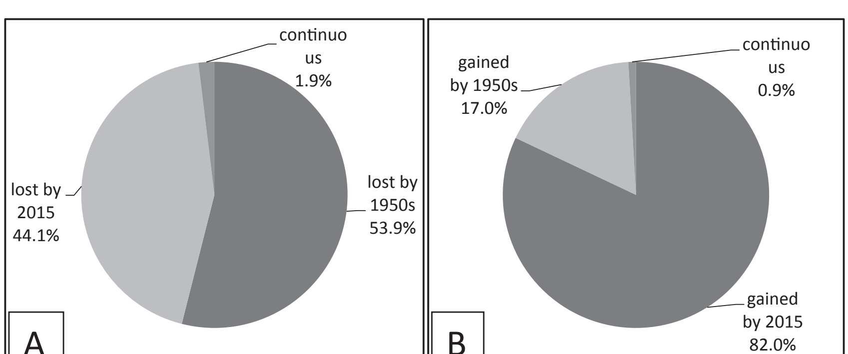

Fig. 2. Continuity of wood-pastures present in 1824–1843 (A) and in 2015 (B).

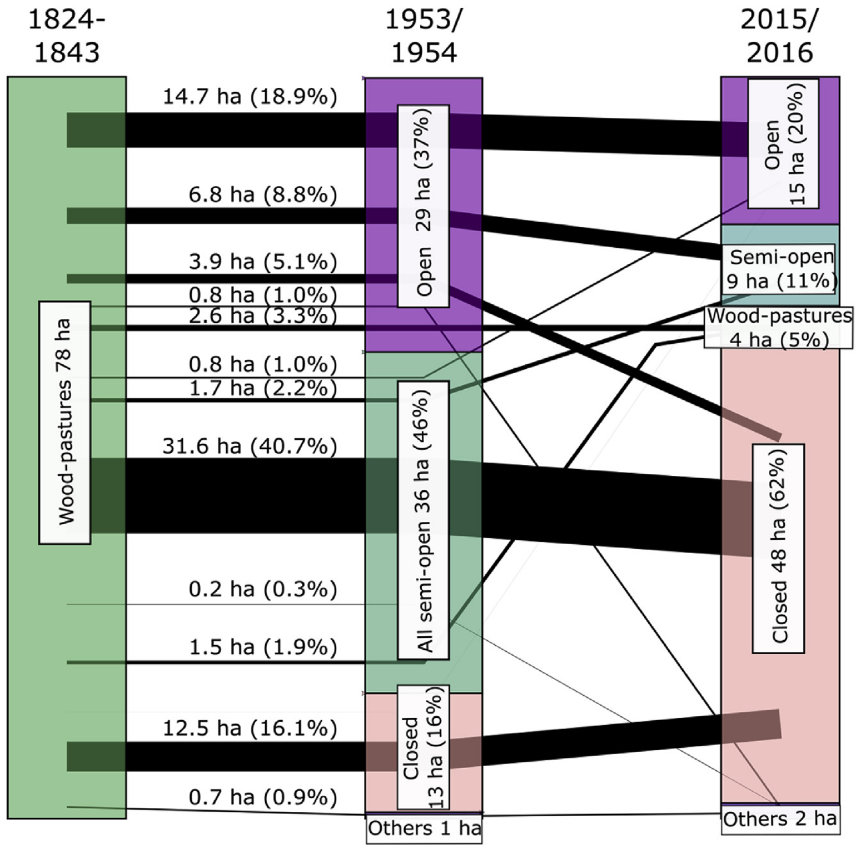

Fig. 3. Change trajectories of wood-pastures present in 1824–1843.

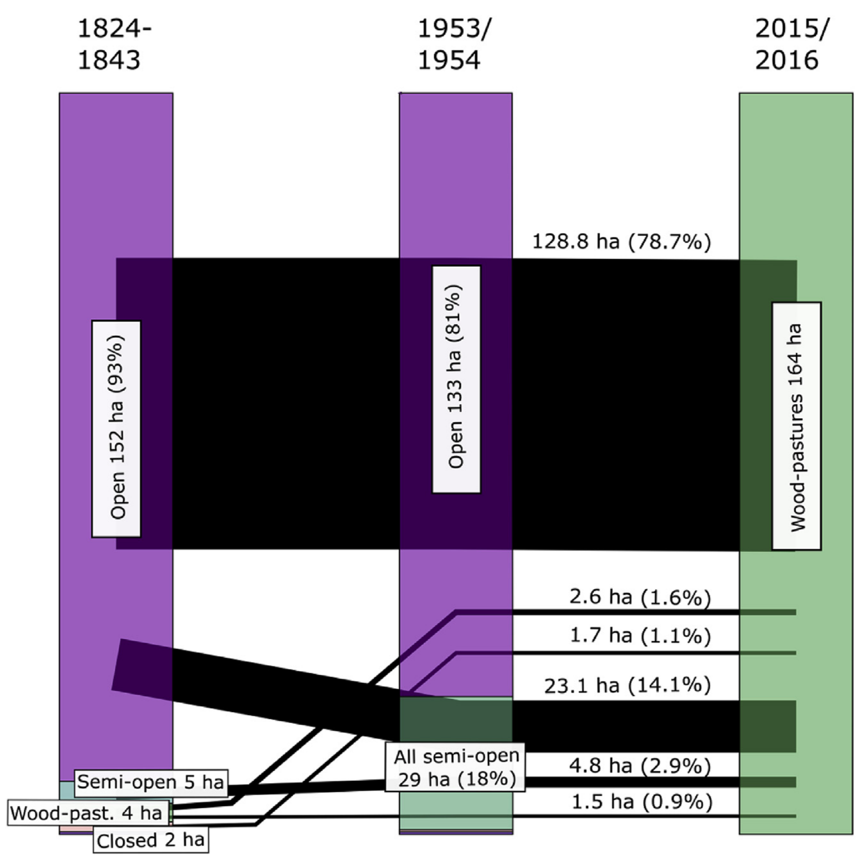

Fig. 4. Change trajectories of wood-pastures present in 2015.

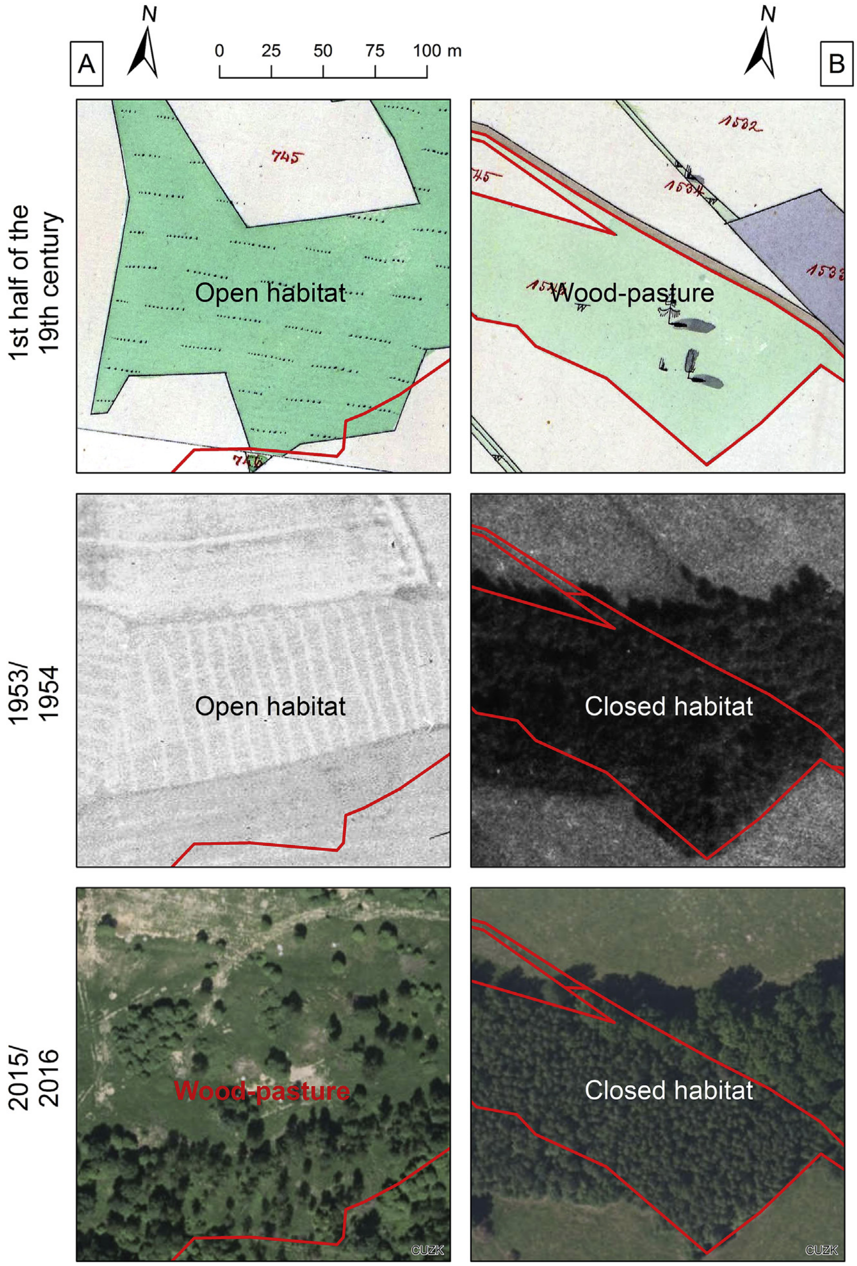

Fig. 5. Examples of typical change trajectories of wood-pastures present in 2016 (A) and wood-pasture present in the 1st half of the 19th century (B).

with shrubs could sometimes be classified as open habitats as the shrubs are not clearly displayed in the orthophoto. This can be confirmed in further studies using archival sources. The major disadvantage of the method of visual interpretation of aerial images consists in its great time demands and sensitivity to the individual manner of work of each particular researcher, which may result in problems in distinguishing between different LULC categories.

Old maps and aerial photographs together with statistical data

Table 2
Limits and assets of the different graphical data sources used for description and analysis of LULC at different temporal horizons.

	1824–1842: Imperial imprints of the Stable Cadastre	1950s: archival orthophoto	2015/2016: orthophoto, field mapping, LPIS, thematic layers
Advantage	Large scale mapping; existing classification of landscape segments	Detectible land cover	Diversity and availability of sources guaranteeing access to any information
Disadvantage	Lack of information upon land cover (abundance and location of trees and shrubs at the plot)	Need of classifying the landscape segments; lack of information upon land-use (grazed/not grazed); low resolution of orthophoto, leading to uncertainty in locating shrubs	Time demanding, need of classifying the landscape segments

about land use are the sole solid data on land use/cover changes, but they should be interpreted carefully. First, the data gained from the sources are related to mapping time horizons, but multiple or repetitive changes between the mapping horizons remain unknown. It is impossible to depict all changes in the model areas, and the interpretation stresses the trends. Secondly, the earliest accurate sources come from the beginning of the 19th century. Information about previous land use changes is scattered and often omitted but the centuries before the 19th century could not be assumed to be unchanging. Finally, the depiction of semi-open habitats on data sources from three temporal horizons does not necessarily imply the existence of wood-pastures with ancient trees in the current landscape. The maps only serve to identify potential habitat continuity and consequent high conservation value (Pătru-Stupariu et al., 2013).

5. Conclusion

The results of the research allow the questions posed in this study to be answered. Firstly, it can be concluded that most wood pastures have not been continuously present in the three studied temporal horizons (1st half of the 19th century, 1953/1954, 2015/2016). Moreover, the wood-pastures present in 2015/2016 were formed mostly in the last 60 years. The source of wood-pastures present now are most often open-habitats, which means that we cannot expect old trees on them.

On the other hand, a little less than half of wood-pastures from the 1st half of the 19th century remained semi-open habitats until the 1950s, which indicates a relatively stable landscape in the first period. However, the process of agricultural intensification was stronger at that time, as more wood-pastures areas were converted into open-habitats than into forests. In the second studied period, rapid transitions of semi-open habitats into forest took place. Indeed, the socialist and post-socialist era was characterized by the abandonment of remnants of wood-pasture land use. Now, wood-pastures are emerging again, although they are valued rather as species rich grasslands which started to be overgrown by woody vegetation and thus need grazing as a conservation management tool.

The overall changes which are presented in the current study, where we described the huge increase in the area of wood-pastures, cannot be generalized for all warm lowlands and moderately warm landscapes of hills and basins. We wanted to study the habitat continuity and change trajectories especially with consequences for current wood-pastures so we chose only those cadastral districts where wood-pastures cover at least 0.5% of the district's area.

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5. The current status of orchard meadows in Central Europe: Multi-source area estimation in Saxony (Germany) and the Czech Republic

Michal Forejt, Ralf-Uwe Syrbe

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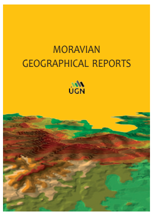

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The current status of orchard meadows in Central Europe: Multi-source area estimation in Saxony (Germany) and the Czech Republic

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Abstract

Orchard meadows are appreciated as an integrated land use of high cultural and biological value. While such meadows are typical habitats for temperate Europe, they experienced a decline in their total area during the second half of the 20th century, both in Western and Eastern Europe. In this contribution, we compare their current area and status in terms of semantics, law, public support in general, and the efficiency of public support in both Saxony and the Czech Republic. We estimated the area in Saxony on the basis of three public mapping projects. In the Czech Republic, where no recent mapping included orchard meadows as a specific land-use type, we carried out our own mapping. Hence, we mapped 124 randomly selected plots of 1 km^2. To cross-reference results from both countries, we used the pan-EU project LUCAS (Land Use/Cover Area frame Survey). According to various different sources, the orchard meadows cover 0.09–0.55% of Saxony and 0.01–0.72% of the Czech Republic. Interestingly, the results of the three mapping projects conducted in Saxony vary from each other. Although orchard meadows are supported by financial incentives of the respective governments in both countries, the Saxon approach concentrating more on individual activities (sanitation of old trees, planting, grassland management), seems more focused than the single measure practised in the Czech Republic. One key to a greater public awareness of the orchard meadow problematic can lie in the promotion of a simple expression referring to this specific landscape feature in Czech, similar to the phrase common in the German language: 'Streuobstwiese'. Our suggestion for the Czech language is: 'luční sad'.

Keywords: *Orchard meadow; Streuobst; LUCAS; agricultural policy; Germany; Czech Republic*

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1. Introduction

Orchard meadows are a phenomenon authentic to cultural landscapes in temperate Europe, spreading from the Atlantic coast (pré-verger in French) to Central Europe (Streuobstwiese in German) (Herzog, 1998). They are characterised by fruit trees with high stems, sparsely distributed on either mowed or grazed grassland. The fruit trees are ordinarily of many types and varieties and of various ages.

Orchard meadows have high ecological value as biotopes (Horak et al., 2013; Thiem and Bastian, 2014; Zillich-Olleck and Bauschmann, 1991). The fruit trees serve as a substitute habitat for birds (Kajtoch, 2017) and saproxylic beetles (Horak, 2014), while species-rich grasslands often grow underneath them (Žarnovičan et al., 2017). Due to the fact that orchard meadows generate a multitude of ecosystem services and maintain biodiversity, they are valuable elements of green infrastructure in both urban and rural areas. Orchard meadows are connected to traditional ecological knowledge (Žarnovičan, 2012), cultural ecosystem services such as recreation and education (Ohnesorge et al., 2015), and the preservation of gene banks for many local fruit tree varieties (Fischer, 2007). For regulating ecosystem services, orchard meadows provide pollination, climate regulation, flood mitigation, erosion control and water purification (Herzog, 1998). Orchard meadows both grace traditional rural landscapes (Thiem and Bastian, 2014) and can construct the green infrastructure of modern cities (Tóth and Timpe, 2017).

In contrast to the above-mentioned ecosystem service values, the decrease in the economic importance of orchard meadows is attributed to transformations in fruit supply

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chains. Specifically, there is an overall move to intensively managed orchards and the separation of integrated land uses into singular ones – fruit production in one place and arable land or grassland in another (Herzog, 1998). The fruit production of orchard meadows is perceived as one of the most vulnerable and important ecosystem services in the cultural landscape of the Swabian Alb (Plieninger et al., 2013).

This form of traditional agroforestry has been recently surpassed by modern agroforestry systems (Nerlich et al., 2013). Orchard meadows are mentioned as a threatened feature of traditional landscapes (Antrop, 2005). After the expansion of fruit trees during the 18th and 19th centuries and the peak of orchard meadows in the middle of the 20th century, numbers have declined throughout the second half of the 20th century in both democratic and socialist parts of Europe (Herzog, 1998). The decline of the total orchard meadow area was reported in eastern Germany as 37% in the period 1968–2008, which was the largest decrease among the studied types of 'trees outside forests' (other types discussed were hedgerows, isolated trees or woodlots: Plieninger et al, 2012). The decline was stronger in north-western Germany, with a 74% decrease from 1979 to 2009 (Umweltbundesamt, 2010, p. 89). A milder decrease (22%) was recorded in south-western Germany during a similar period (Plieninger et al., 2015b), and in some locations there was even an increase during the last century (Plieninger, 2012). Radical decline of the orchard meadows area was reported from central Slovakia between 1950 and 2010 (Hanušin and Lacika, 2018). The area of non-forest woody vegetation, including fruit trees and a number of individual features, declined in the second half of the 20th century in the hilly region of eastern Czech Republic (Demková and Lipský, 2015).

At present, orchard meadows are further threatened by agricultural intensification, urbanisation (Plieninger et al., 2015b), and the abandonment of undergrowth and tree management (Milton et al., 1997; Demková and Lipský, 2015). As described for the case of Slovakia, many orchard meadows are managed by the elderly, and thus the land maintenance in rural regions is threatened by the loss of traditional approaches and emigration of younger generations to urban regions (Špulerová et al., 2015; Žarnovičan, 2012).

Despite a certain level of public support for the managers of orchard meadows, it is not enough to guarantee a sustainable maintenance of current plots, and woefully insufficient for the establishment of new plots, as was shown in Lower Austria (Schönhart et al., 2011) and the Dresden area (Ewert, 2018). There have been measures proposed directly for improving orchard meadow policies, such as adding orchard meadows to the habitat list of Annex 1 (92/43/CEE Directive) (Kajtoch, 2017), or increasing premiums within the framework of the Agri-Environmental Policy (Schönhart et al., 2011). Some authors have suggested new management practices: for example, increasing harvest efficiency by shared mechanisation; providing an added value to the fruit by processing it (Schönhart et al., 2011); introducing the cultivation of energy crops in the understorey; and intensifying the processing of fruit into juices (Plieninger et al., 2013).

One problem with such measures is that many orchard meadow managers regard farming as a hobby, and they can be an inefficient target for agricultural subsidies since they often do not qualify for the minimum requirements of said subsidies (Ohnesorge et al., 2015). One general ambition, then, is to raise public awareness and connections to some regional identity, resulting in higher local fruit consumption and the successive creation of new orchard meadows (Rost, 2011).

To create good policy and strategies, it is necessary to know how important is the role that orchard meadows play in the landscape, beginning with how much area they cover. One estimate is that 10,500 km^2 of the European Union is occupied by grazed or intercropped areas with fruit, olive, and nut trees (den Herder et al., 2017). Another estimate, based on different sources from the end of the 20th century, comes to similar results, namely that 10,000 km^2 of Europe is covered by scattered fruit trees (Herzog, 1998). Den Herder et al. (2017) estimate there are 358 km^2 of grazed areas with fruit trees in Germany (0.1% of the total area), while Herzog (1998) states that there are 2,250–5,000 km^2 of orchard meadows in Germany, which amounts to 0.6–1.4% of the country's total area (note the difference between the objects under review). Germany's eastern neighbour, the Czech Republic, is said to have 72 km^2 of grazed orchards (0.09%: den Herder et al., 2017) or 93 km^2 of orchard meadows (0.12%: Herzog, 1998). Rapid declines are also evident here: in the first half of the 19th century, 0.64% of Bohemia (the historical territory: 2/3 of the present-day Czech Republic) was covered by agroforestry land with fruit trees (Krčmářová and Jeleček, 2017).

Several themes emerge as relevant for this paper. To accomplish better conservation and restoration of orchard meadows and to raise the appreciation of biodiversity and ecosystem services, a common terminology is required. Secondly, comparisons beyond European borders should give insights as to how this type of an ecosystem can be protected at an international scale, where subsidies already exist and what (EU) policy can do to maintain it. Finally, knowledge is needed about the precision of geo-data for this ecosystem type, about the available data to measure them and about their validity.

Therefore, the paper first clarifies the semantics of German and Czech terms, compares them and gives suggestions on how exactly to nominate this specific type of orchards in national debates. Second, the legal status and system of agricultural subsidies in both neighbouring countries are outlined. Third, we try to increase the precision of the estimated area of orchard meadows and their spatial distribution in the Czech Republic and Saxony, one federal state of Germany. The reason for choosing only one federal state in Germany is that Saxony has specific legal conditions in nature conservation, as well as completed unique land-use and vegetation mapping projects depicting orchard meadows. A similar approach is used for the Czech Republic and allows us to make a one-to-one comparison.

Previous studies had severe insufficiencies, namely den Herder et al. (2017), which took into account only those areas with fruit trees that are grazed, and Herzog (1998), which estimated the area based on non-explicit sources, for example relying on data from the Czech State Statistical Office despite orchard meadows not being explicitly recorded there. The present study is based on the multiple geodata approach. But first, we will discuss the current linguistic and legal status of orchard meadows in Saxony and the Czech Republic, and then we will continue to scrutinise orchard meadow support measures and estimate their efficiency.

2. Current status

2.1 Semantics

The English term 'orchard meadow' started to be used by researchers from German-speaking areas who were trying to find an equivalent for the word *Streuobstwiese*[1] (Ohnesorge et al., 2015; Schönhart et al., 2011; Steffan-Dewenter and Leschke, 2003). Another term we can encounter in English-language-based scientific literature is a 'traditional orchard', used in studies from Poland, Slovakia or the Czech Republic (Horak, 2014; Kajtoch, 2017; Špulerová et al., 2015; Žarnovičan et al., 2017). The most precise, but much longer, translation of *Streuobstwiese* is 'scattered fruit tree meadow' (Thiel et al., 2012).

Concerning the Czech language, there is the common word sad, which is equivalent to the English 'orchard'. It includes both intensively and extensively managed stands of fruit trees, which may also be ploughed. Expressions referring to extensively managed orchards are *extenzivní sad* and *vysokokmenný sad*[2]. In comparison to the German Streuobstwiese, these Czech expressions feel very professional, and they are used mostly by experts in conservation. There are also terms dividing orchards by the secondary use of the understorey, i.e. *polní sad* (when intercropped), *luční sad* (when mowed), or pastevní sad (when grazed). In Slovak, very similar to Czech, the term *sadová lúka*[3] is sometimes used (Žarnovičan, 2012) to refer to the orchard meadow concept in general.

2.2 Legal status – conservation

Orchard meadows are not listed as a protected habitat in Annex I of the Habitats Directive of the Council of the European Communities (Council of the European Communities, 1992), nor in Article 30 of the Federal Nature Conservation Act (BNatSchG, 2019), which is valid for Germany as a whole. Some German federal states, however, do list orchard meadows as nature conservation objects. The Saxon Nature Conservation Act (SächsNatSchG, 2018) mentions orchard meadows (*Streuobstwiese*) in the list of protected biotopes (§21 Art 1 No. 4), which means that any action that can lead to the destruction or damage of the biotope is forbidden (cf. BNatSchG, Art 30 No. 2). According to one commentary to the Saxon Nature Conservation Act (Göttlicher, 999), an orchard meadow must cover an area of 500 m^2 and must grow 10 trees at a minimum to qualify as a *Streuobstwiese*. The Czech Nature and Landscape Conservation Act (ZOPK, 2017) generally obliges all owners of trees to care for them. There is also an instance of 'remarkable tree', which ensures stricter protection, though this is used only in exceptional cases.

2.3 Public support

In both the Czech Republic and Saxony, specific measures supporting orchard meadows maintenance have been implemented. The Czech measure supported by the second pillar of the Common Agricultural Policy (CAP) for organic farming is called Krajinotvorný sad ('landscaping orchard'). Conditions to get this subsidy contain: growing high- or middle-stemmed trees to a minimum density of 50 trees per hectare (with a density greater than 100 trees/ha, a different program is more suitable). The trees must grow on once-a-year mowed or grazed grassland. Furthermore, farmers have to commit to work under the specified conditions for at least five consecutive years, and the trees have to be clipped at least once in the first four years after planting (Ministry of Agriculture of the Czech Republic, 2016). Together with basic and greening payments, each farmer, who is registered as an agricultural entrepreneur by the ministry of agriculture, can get approximately EUR 365/ha/year for managing the land in this way. There were 771 field blocks thusly supported, accounting for 1,009 ha (0.013% of the Czech Republic) in total, according to government statistics from January 2018 (Ministry of Agriculture of the Czech Republic, 2018).

Orchard meadows in Saxony are eligible for support from the program Richtlinie Natürliches Erbe ('Guidelines for Natural Heritage'). This program concerns, among other topics, the sanitation of old fruit trees and planting of new fruit trees. The first goal is supported by EUR 41 (easy conditions) or EUR 75 (hard conditions) per tree, with a minimum support for one project of EUR 500 (thus, a minimum of 7 trees per project in hard conditions). Following this, one newly planted tree is supported by EUR 68 with the same minimum sum per project (resulting in at least 8 new planted trees per project). Since 2014 when the program was established, 3,907 existing trees in 68 projects have been subsidised, an average of 58 trees per project (as of Spring, 2018). During the same period, 3,866 new trees were planted in 57 projects, an average of 68 trees per project. More than twenty (22) supported projects covered both planting and restoration, although it is unclear how much they contribute to the numbers mentioned above. Thus, we can roughly estimate that at least 100 plots in Saxony have been supported by the National Heritage program. The management of grasslands can be supported by a similar measure (Richtlinie Agrarumwelt- und Klimamaßnahmen).

Both in the Czech Republic and Saxony it is possible to request direct payment for grassland management within the first pillar of CAP. There are also other publicly- and privately-funded programs aimed at the planting of new fruit trees.

3. Methods

To estimate the total area of orchard meadows in Saxony and the Czech Republic, we used several existing datasets (their basic properties are shown in Tab. 1), one adjusted pan-EU data source, and researcher-mapped randomly selected plots. Other comparable data sources do not differentiate orchard meadows well enough: for example, the Corine Land Cover uses the class 2.2.2 (Fruit tree and berry plantations), which matches orchard meadows with the intensive type of plantations. Moreover, Corine Land Cover uses a minimum mapping unit of 25 ha, which is inappropriate to estimate the area of orchard meadows, with their typical small scale. Because each country has different types and the extent of data sources available, our approach differs for the different states, though it is cross-referenced with the use of the LUCAS (Land Use/Cover Area frame Survey) grid data.

[1] *Streuen* = scatter, *Obst* = fruit, *Wiese* = meadow. Sometimes the word Streuobst is also used (Herzog, 1998; Tojnko et al., 2011), which includes intercropped orchards and such landscape elements as fruit alleys, etc.

[2] Direct translation to English: 'orchard with high-stemmed fruit trees'

[3] Direct translation to English: 'orchard meadow'

Country	Dataset	Years of origin	Min. registry unit (ha)
Saxony	SBK2	1996–2002	0.05
Saxony	BTLNK	2005	0.05
Saxony	ATKIS	2013–2016	1.00
Czech Republic	LPIS	2018	0.50
EU	LUCAS	2015	0.05

Tab. 1: Analysed data sets on orchard meadows
Sources: Selektive Biotopkartierung 2. Durchgang (SBK2) = Selective habitat mapping; Biotoptypen- und Landnutzungkartierung (BTLNK) = Mapping of biotope types and land use; Amtliches Topographisch-Kartographisches Informationsystem (ATKIS) = German digital topographic information system; LPIS – Land Parcel Identification System; LUCAS = Land Use / Cover Area frame Survey

3.1 Saxony

There were three independent projects conducted in Saxony, which mapped orchard meadows as spatially delimited patches.

Selective biotope mapping 'SBK' (Selektive Biotopkartierung = Mapping of selected biotopes; LfULG, 2002) in Saxony is thought to record all biotope types that are protected by federal and state nature conservation laws (BNatSchG, 2019; SächsNatSchG, 2018). SBK was used as bases for the administrative work of the nature conservation agency. The mapping was carried out on-site by experts, basing it on the already-existing BTLNK (see below). After completion of the first pass in 1994, a second pass 'SBK2' was carried out between 1996 and 2002. Since this second set was only partially revised by the third pass in 2006–2008, SBK2 provides the last available complete dataset. Since 2009 no revision has been carried out, so while the SBK data are very precise they are also potentially out of date. Because every biotope type was mapped and described in great detail to make a sophisticated data set, some smaller areas were described only as biotope complexes, such that an exact calculation of the real biotope area is rather difficult (Syrbe et al., 2018).

A complete aerial-covering biotope mapping 'BTLNK' (Biotoptypen- und Landnutzungkartierung = Mapping of biotope types and land use) based on colour-infrared aerial views was carried out in Saxony in the years 1992, 1993 and 2005. The recent data set is available from the Saxon Nature Conservation Agency (LfULG, 2005). The resulting digital biotope maps can be more precisely spatially analysed, but since they use remote sensing data, their precision is limited; in other words, shortcomings and confusion with other similar biotopes are an ever-present possibility.

The landscape model of the German digital topographic information system (ATKIS-Basis-DLM = Amtliches Topographisch- Kartographisches Informationsystem – Basis Digitales Landschaftsmodel; SGVSG, 2016) is updated separately by each federal state in Germany. The stage of project development varies among the German states. The classification system contains 190 object types. The minimum mapping unit for this system is 1 ha and therefore coarser than SBK2 and BTLNK (Tab. 1), and updates are carried out using aerial photography and more thematic details. Since then, the topographic data have been updated using high-resolution remote sensing data (SGVSG, 2016).

Based on these three projects, which spatially differ between each other, we constructed an intersection diagram expressing the probability for orchard meadow occurrence in Saxony. We assume that the probability of identifying orchard meadows is higher the higher the number of available data sources, particularly considering that newer sources tend to be more credible than the older ones.

3.2 Czech Republic

There is only one data source that spatially delimits orchard meadows in the Czech Republic, the Land Parcel Identification System (hereinafter LPIS). LPIS registers the land for which the discussed agricultural subsidies are provided. We took the field blocks with land use registered as 'landscaping orchard' as patches with a certain occurrence of orchard meadows. The minimum area of one field block is set to 0.5 ha.

Because these field blocks with 'landscaping orchard' land use refer only to orchard meadows registered for their organic management and receiving subsidies, we further estimated their area on the basis of our own mapping in randomly sampled squares of 1 km^2. We performed the whole analysis in ArcGIS 10.5.1 (ESRI). To assure that the squares would be equally spread across the country, we used the Create Fishnet tool to create squares of 25 km per side (an area of 625 km^2). Polygons smaller than 625 km^2 were created around the country border. In each polygon larger than 300 km^2 (i.e. approximately half of 625 km^2) we placed one sampling square. We used the Random points tool to randomly place points and the Graphic Buffer tool to build squares around the points. Using this procedure, we prepared 124 squares of 1 km^2 to be mapped. The sampling method was arbitrarily set up to give a coarse overview of the spatial distribution of orchard meadows throughout the Czech Republic.

We mapped the orchard meadows in the delimited squares on the basis of orthophoto maps provided as a web map service by the Czech Office for Surveying, Mapping and Cadastre (2016, 2017). We further used the Basic map of the Czech Republic to check for gardens and orchards for identifying patches with present fruit trees. We also used the tool Panorama at mapy.cz (the Czech equivalent to Google StreetView) to check the height of the trees and their undergrowth. Single field visits in three squares showed us that this approach is suitable (see photos on Fig. 1). The method used is comparable to one of the BTLNK and ATKIS sources which did not do on-site mapping, though we used additional sources to remote sensing. The definition used to identify orchard meadows comes from the Saxon Nature Conservation Act. We considered orchard meadows only of at least 500 m^2 in area size and with 10 or more high-stemmed trees scattered (approximately 20–200 trees/ha) across grassland undergrowth. A certain level of successive overgrowth was accepted.

Fig. 1: The appearance of visited orchard meadows in northern Czech Republic: Moderately managed orchard meadow situated between home gardens and a forest in the recreational settlement of Bukovec (top left); Overgrown orchard meadow situated not far from the village Krušovice near Rakovník (top right); Intensively managed orchard meadow near the centre of Zíchovec village (bottom left); Orchard meadow with old apple trees threatened by the construction of a bypass route, Krušovice village (bottom right). Photos: M. Forejt

3.3 Central European context

We further used the LUCAS grid database to compare and cross-reference the results obtained from the defined datasets from Saxony and the Czech Republic. The LUCAS database, purchased in 2015, is comprised of 273,153 field-surveyed and 66,604 photo-interpreted geo-referenced points (Eurostat, 2015). For each surveyed or photo-interpreted point, land use, land cover, and other data were recorded. It covers only the 28 member states of the EU, thus Switzerland and Lichtenstein, both of which are normally considered Central European countries, were not included. Previously, the database was used to estimate the extent of wood pastures (Plieninger et al., 2015a) and other various types of agroforestry (den Herder et al., 2017).

Both studies, when considering land with fruit trees, took into the account only land with grazing management, although orchard meadows (no matter if grazed or not) are generally considered a type of agroforestry (Nerlich et al., 2013). Here, we only selected points with fruit trees as primary land cover [LC1 (primary land cover) = B71–B75 (apple trees, pear trees, cherry trees, nuts trees and other fruit trees and berries)], and we further used orthophoto and LUCAS PhotoViewer to adjust photos from each site and to verify each point for fruit tree density, stem height, and grassland undergrowth.

We applied the same definition of orchard meadows as before, including the minimum area (500 m^2) and minimum number of trees (10). We performed this procedure for all Central European countries that are EU member states (Germany, Austria, Poland, Czech Republic, Slovakia, and Hungary). The share in area of one geographic unit was estimated by dividing the number of points matching the criteria by the number of all points for each state in the Central Europe region (den Herder et al., 2017).

4. Results

Table 2 presents geographical coverage of orchard meadows in the Czech Republic, Saxony, and other parts of Central Europe. Regarding to the LUCAS database, not all the fruit trees points are registered, but only those have been manually selected that doubtless represent orchard meadows with high-stem scattered trees. Relatively low values (compared to marginal distributions of orchard meadows and total acreage) are found in Hungary and Poland, while the relatively highest values are those from the Czech Republic and Slovakia. Detailed findings are presented in subsequent sections.

4.1 Saxony

According to the individual mapping projects, there are 44.1 km^2 (0.24% of Saxony's total area; SBK2), 61.5 km^2 (0.33%; BTLNK), or 15.8 km^2 (0.09%; ATKIS) of orchard meadows in Saxony (see Fig. 2). The minimum overlap between all projects is 6.1 km^2 (0.03% of Saxony). Areas where at least two of these mapping projects agree on the occurrence of orchard meadows amounts to 26 km^2 (0.14% of Saxony), while areas where at least one project shows the occurrence of an orchard meadow is 86.3 km^2 (the potential maximum area of orchard meadows without considering different mapping criteria; 0.47% of Saxony). The interpreted LUCAS database suggests even more, namely that 0.54% of all points in Saxony are orchard meadows. The mean patch size of one orchard meadow is highest according to ATKIS (1.8 ha), and more than three times smaller according to both BTLNK (0.54 ha) and SBK2 (0.46 ha).

Orchard meadows are concentrated in central Saxony (the districts of Leipzig, Mittelsachsen, Meißen, Sächsische Schweiz-Osterzgebirge, and Dresden) in a wide strip

Geographic unit	Dataset	km²	%
Saxony	SBK2	44.1	0.24
	BTLNK	61.5	0.33
	ATKIS	15.8	0.09
	SBK2+BTLNK+ATKIS	6.1–86.3	0.03–0.47
	LUCAS	99.7	0.54
Czech Republic	LPIS	10.1	0.01
	Random squares	437.0	0.55
	LUCAS	566.0	0.72
Austria	LUCAS	360.6	0.43
Germany		1924.1	0.54
Hungary		180.0	0.19
Poland		623.2	0.20
Slovakia		356.0	0.73
Central Europe		4009.9	0.41

Tab. 2: Orchard meadow areas in Central Europe according to multiple sources.
Sources: Ministry of Agriculture of the Czech Republic (2018), Eurostat (2015), BKG (2016), LfULG (2002), and LfULG (2005); authors' survey

starting south of Dresden, spreading northwest to the town of Meißen and west between the cities of Leipzig and Chemnitz. Concerning landscape units, orchard meadows are concentrated in Mittelsächsisches Lösshügelland ('Central Saxon loess landscape') and Östliches Erzgebirgsvorland ('Eastern Ore Mountains foothills') (Mannsfeld and Syrbe, 2008). There is a significant difference between the spatial coverage of orchard meadows in the three mapping projects. In the southwestern part of Saxony, there is a relatively high share of mapped orchard

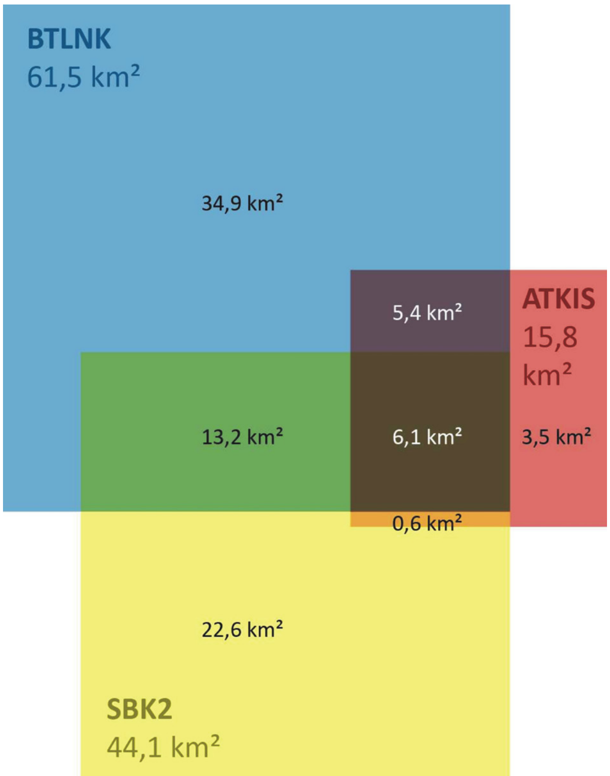

Fig. 2: Concordance in mapped orchard meadows in mapping projects in Saxony. Sources: BKG (2016), LfULG (2002), and LfULG (2005); authors' elaboration

meadows in the BTLNK dataset, while SBK2 reports large areas of mapped orchard meadows in the east and in the Meißen district (see Fig. 3).

4.2 Czech Republic

The LPIS system for registering land that receives agricultural subsidies, records 1,009 ha of orchard meadows (0.013% of the Czech Republic total area) in 771 field blocks in the Republic. They are mostly present in south-eastern, eastern and northern areas of the Czech Republic, where registered orchard meadows may reach up to 0.05% of the respective region's total area (see Fig. 4A). Concerning landscapes rather than administrative units, orchard meadow hot spots seem to occur in the Bílé Karpaty ('White Carpathians'), Ždánický les ('Zdanice Forest), Český ráj ('Bohemian Paradise'), and České středohoří ('Central Bohemian uplands') landscapes.

According to our digital mapping (Fig. 4B), 46 of the 124 mapped squares contained at least one patch of orchard meadow. Altogether we identified 68.7 ha of orchard meadows. The maximum orchard meadow share in one square was 12.8% (near the town of Kyjov), and the minimum share was 0%, which was true for 78 squares. 12 squares contained at least 1% of orchard meadows. Taking all the mapped squares together, we can calculate the average occurrence of orchard meadows in the Czech Republic as a 0.55% share of the country's total area. Again, there are apparent orchard meadows hot spots, especially eastern and partly in northern Czech Republic, and the south-western half of the Czech Republic does not show a high concentration of orchard meadows. One square, near the town of Rakovník, is a notable exception to this rule. Using the LUCAS database, we can estimate that 0.72% of the Czech Republic is occupied by orchard meadows.

4.3. Central Europe

In the context of Central Europe, the LUCAS database reveals that orchard meadows have the highest shares of land use in Slovakia (0.73%) and the Czech Republic (0.72%). The lowest shares, meanwhile, occur in Hungary (0.19%) and Poland (0.2%). Orchard meadows in Germany and Austria have average values (0.54% and 0.43%, respectively), which is due to very large areas with a very low density of points identified as orchard meadows (the Alps and North-German lowland).

Concerning the spatial distribution in Central Europe specifically (see Fig. 5), high concentrations of orchard meadows are found, not surprisingly, in Baden Württemberg, northern Bavaria, the Rhineland, eastern Saxony (all in Germany), in Steyerland (Austria), and the western Carpathians (western Slovakia, southern Poland, eastern Czech Republic), mostly between 100 m and 500 m above sea level (maximum at 1,135 m in the Alps in Austria).

Only very rare occurrences are found north of 52° latitude or in the whole of Hungary. Concerning our focal countries, low densities of orchard meadows are recorded in south-western Saxony and north-western and north-eastern Czech Republic (Fig. 5).

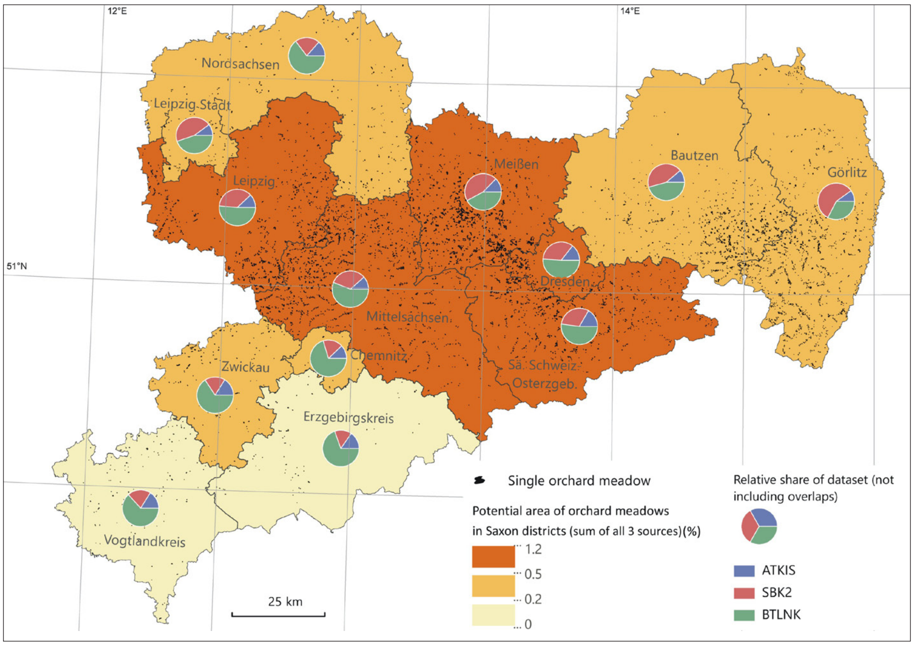

Fig. 3: Share of orchard meadows in Saxon administrative districts
Sources: BKG (2016), LfULG (2002), and LfULG (2005); authors' elaboration

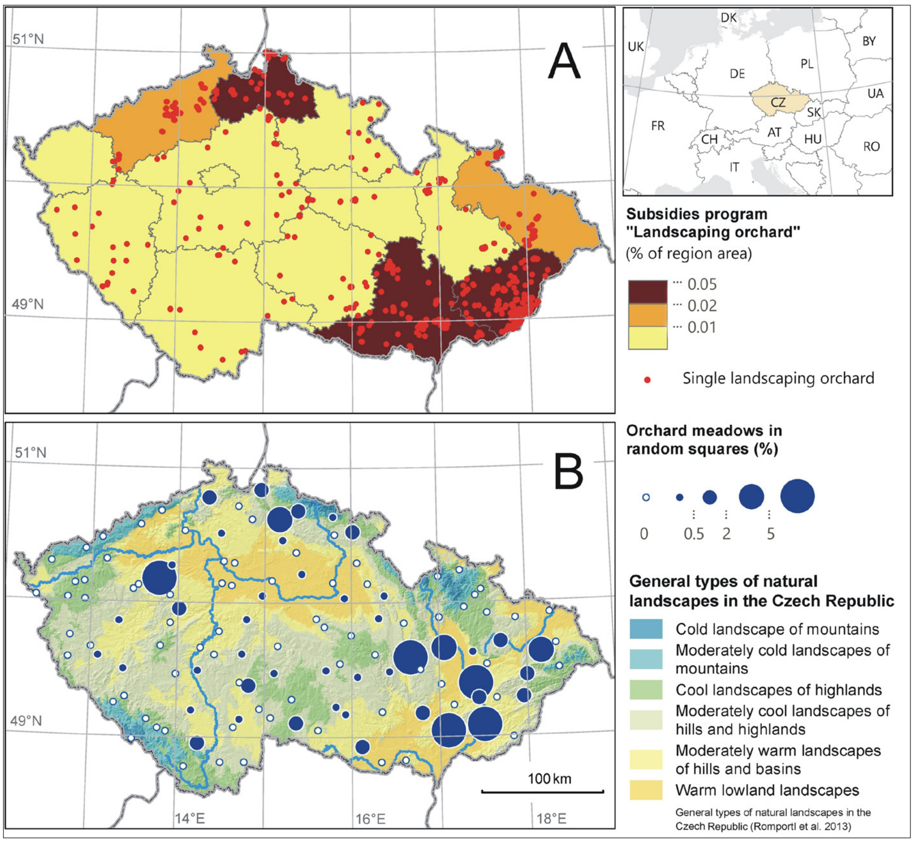

Fig. 4: The share of orchard meadows in the Czech Republic according to: A) LPIS (January, 2018); and B) authors' mapping based on aerial images (ČÚZK, 2016, 2017) and mapy.cz street view application. Sources: Ministry of Agriculture of the Czech Republic (2018), Romportl et al. (2013), authors' survey; authors' elaboration

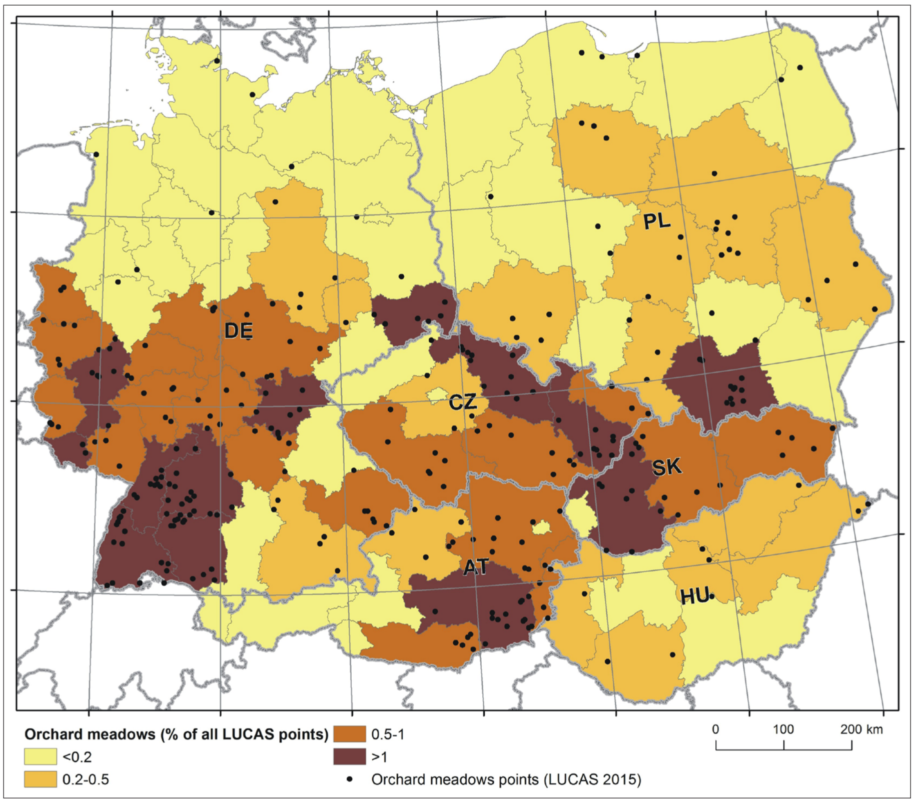

Fig. 5: Share of orchard meadows in Central European NUTS II units according to authors' verification of LUCAS points with fruit trees. Source: Eurostat (2015); authors' elaboration

Table 3 shows the share of points with interpreted orchard meadows in all mapping projects against the total point number of fruit trees. The highest values occur in Austria, Germany, and Slovakia, where orchard meadows make up about half of the fruit tree points. Lesser values are exhibited in the Czech Republic and very low shares are recorded in Poland and Hungary.

5. Discussion

Orchard meadows are a landscape feature typical for temperate Europe (Herzog, 1998). We used multiple geodata sources to estimate the area of orchard meadows and their spatial distribution in the Czech Republic and Saxony. Orchard meadows occupy a smaller share of the total area in Saxony than orchard meadows in the Czech Republic. This was confirmed by an additional source we used to cross-reference the results, the LUCAS grid database. In Saxony it is the central part of the territory that has the highest density of orchard meadows. South-eastern and northern Czech Republic are also characterised by high concentrations of orchard meadow plots. We do not consider the mapping of 124 random squares sized 1 km^2 each, however, to be a detailed orchard meadow distribution survey for Czech regions, rather we consider it to be an approximate localisation of large orchard meadow hot-spots.

Our study revises the previous area estimation of the total orchard meadow area in the Czech Republic. We estimate that the area is almost five times larger than the previous, often cited, estimate (Herzog, 1998). The present estimation suggests only a 15% decline since the mid- 19th century in Bohemia, which accounts for two thirds of the current area of the Czech Republic (Krčmářová and Jeleček, 2017).

According to LUCAS, the share of orchard meadows in Saxony is higher than what other data (SBK2, BTLNK, ATKIS, random squares own mapping) would leave us to believe. It is apparent that this widely-used source (den Herder et al., 2017; Plieninger et al., 2015a) overestimates the area of orchard meadows. Since only accessible points located lower than 1,200 m above sea level are included in the LUCAS dataset, the reason for the overestimation could be that orchard meadows are usually located in

Country	LC1 = fruit trees	Orchard meadows	Share OM/Fruit trees (%)
Austria	73	38	52.1
Czech Republic	121	41	33.9
Germany	273	144	52.7
Hungary	64	10	15.6
Poland	364	46	12.6
Slovakia	42	20	47.6

Tab. 3: Share of orchard meadows on all plots with fruit trees in Central Europe according to LUCAS and own visual evaluation of photos (Note: this is not share of orchard meadows to total area [cf. Tab. 2])
Source: Eurostat (2015); authors' elaboration

close proximity to villages and in rather hilly areas (Herzog, 1998). The area of land-uses with a similar spatial distribution (e.g. built-up area, gardens), is probably also overestimated, while land-uses typical for remote areas are underestimated in LUCAS. This important hypothesis should be tested in the future.

The LUCAS database, however, does give an overview and the possibility for comparison between several states and countries. When we compare different sources, especially in the cases of Saxon mapping projects, they agree only to a very small degree in the delimitation of orchard meadows. Such disagreement can be partly explained by the temporal extent of the mapping throughout the 20-year period (from 1996 to 2016). Another reason can be due to different mapping methods, as only SBK2 used on-site mapping, while ATKIS and BTLNK are based on remote sensing. Finally, orchard meadows are a transitional land use and the boundaries between them and the phenomena of gardens, intensive orchards, low-stemmed orchards, high-density fruit tree stands or young fruit tree stands, are very unclear. It presents a good example of the often difficult effort involved in putting landscape features into a single category (Dahlberg, 2015) or even of classifying landscapes (Wolski, 2016).

Regarding the share of orchard meadows among all fruit tree land cover in the LUCAS database, we can conclude that the largest proportions of orchard meadows per total fruit tree growing area are in Austria and Germany. We can also assume a high self-supply of fruit in these countries corresponding to the fact that orchard meadows in the Swabian Alb are often managed by hobby farmers (Ohnesorge et al., 2015). On the other hand, Poland, an important apple producer, has a low share of orchard meadows for the large amount of fruit trees growing in the country.

Considering public support in the two case study areas, one can apply a complex measure for the specific land use (Czech Republic) or separate measures for planting new trees, sanitation of old trees, and management of grasslands (Saxony). In the case of the Czech Republic, only 2% of orchard meadow areas (derived from the estimation based on our mapping of the 124 random squares – an average of 0.55%) receive subsidies designed for this land use in the 'landscaping orchard' program (10.1 km^2 in the country). Paradoxically, in the cases of orchard meadows which were mapped by us, not a single plot was subsidised by any means. The Saxon approach is not based on spatial delimitation, thus we cannot precisely estimate the share of supported orchard meadow areas. We can approximately estimate from data of the number of projects and trees that about 100 plots received support for the planting of young trees and/or the sanitation of old trees. If we take the data from BTLNK, namely the mean orchard meadow size of 0.54 ha and the total area of the orchard meadows of 61.5 km^2, we come to 54 supported hectares, which means that about 0.9% of orchard meadow areas are supported from the two programs. From the above-mentioned, it is apparent that the efficiency of public support towards orchard meadows is low in both Saxony and the Czech Republic.

Orchard meadows are land uses only partly covered by measures of CAP, even though they provide important ecosystem services. A similar case is the wood-pastures in Europe (Beaufoy, 2014; Jakobsson and Lindborg, 2015). This issue is discrepant with respect to the proclaimed intention of CAP to enhance the ecological functions of landscape. The presence of scattered trees on grassland (agroforestry) is considered to be an important climate change adaptation measure, yet as mentioned before, many orchard managers are hobby farmers (Ohnesorge et al., 2015), whose homesteads are not large enough to get public support. Since the orchard meadows are often managed by elderly people (Špulerová et al., 2015), there is a threat that traditional ecological knowledge connected with the care of fruit trees and fruit processing will fade away. Public awareness must be enhanced in both countries to attract younger people to adopt skills from people who still use them. If used, a more effective fruit production or new management practices such as cultivation of energy crops in the understorey, can lead to sustainability and the expansion of orchard meadows. (Schönhart et al., 2011; Plieninger et al., 2013).

One of the first steps to raise awareness of orchard meadows in the Czech Republic is to start using a specific term for the orchard meadows. Among landscape scientists, the term extenzivní sad ('extensive orchard') is used to describe orchard meadows as described above. If the same term were to be used by the general public, it could feel too professional and thus inappropriate. A better option could be luční sad ('meadowed orchard' or 'meadow orchard', where the meadow takes on a descriptive role). It seems important to use the word sad as a noun, rather than, for instance, the term sadová lúka ('orchard meadow', where sad is an adjective) as used in Slovakian research. The word luční (meadow-ish as a descriptor) specifies the type of orchard, sad being the only word used for an area of fruit production in an otherwise open landscape. The method of undergrowth management (whether pasture or mowing) could be deemed comparatively unimportant. Finally, the expression luční sad could be used as a label for products of orchard meadows, similar to the ways in which the word Streuobstwiese is used in relation to juices, jams, etc., in Germany.

6. Conclusion

Orchard meadows represent a landscape feature that is typical for temperate Europe: they provide a multitude of valuable ecosystem services. Based on the research presented in this study, both the Czech Republic and Saxony have high concentrations of orchard meadows in comparison with Central Europe in general. Orchard meadows cover more area in the Czech Republic than in Saxony, although they are protected by law only in Saxony, while the Czech language does not commonly use a distinctive term for orchard meadows let alone for them to be distinctly protected by the law. The information from recently available data sources differ too widely to set up a reliable monitoring program. In particular, data sources about orchard meadow coverage can differ. One estimation method differs from the other by almost 500% in Saxony (ATKIS – LUCAS) and by 7,200% in the Czech Republic (LPIS – LUCAS). The main problem with extracting orchard meadows from thematic maps or statistical data sets lies in the fact that they are a transitional landscape type, without consistent recognition. The highest densities of orchard meadows are located in parts of the Czech Republic and Saxony where biodiversity hotspots are also present. The orchard meadow is a type of traditional agroforestry with not only high historic heritage and recreational values, but also an ecosystem with potentially high resilience towards climate change due to their species and genetic diversity.

Some areas may even be called orchard meadow deserts, however – such as southwestern Czech Republic and the Ore Mountains – as these rather peripheral areas are regarded more for their touristic attractiveness, but they could benefit from a higher orchard meadow density.

The status of nature conservation differs essentially between the study areas. Whereas protection is directed to trees by the Czech legislation, in Saxony it is focused on the orchard meadow as a whole, which is not necessarily the case in the rest of Germany. Even though the latter approach of conservation seems to be more reasonable, regarding the share of orchard meadows on the whole area does not guarantee a higher quantity of this habitat type. Orchard meadows are subsidised from public budgets in both in Saxony and the Czech Republic, although with respect to the percentage of orchard meadows receiving such funds, the support cannot be really called efficient in either of them.

The high awareness of orchard meadows in Germany is generally highlighted by the well-known term (Streuobstwiese), which is frequently and successfully used, e.g. as a sales argument for fruits and juices produced in this sustainable manner. In Czech, a similar awareness could be raised by using the rather new expression luční sad, which feels ordinary and pleasant enough to get public appreciation. Since orchard meadows are often owned and maintained by elderly people, the threat of losing them in a long run must be countered by higher public attention and support. Policy agencies must find better solutions to protect these orchards in several areas, namely by improving the obvious small efficiencies of targetted subsidies and by enhancing overall data quality, so setting target values and their monitoring would be possible in future. We believe that the conservation and development of traditional knowledge connected with the orchard meadows can be raised by general interest, which is already partly being expressed by the activities of young and experienced farmers, NGOs, hobby clubs and public authorities.

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6. Diskuse

6.1 Komentář ke kapitole č. 3: Quantifying inconsistencies in old cadastral maps and their impact on land-use reconstructions.

Tento článek používá, stejně jako mnoho dalších studií v krajinné ekologii, tzv. Františkovský katastr (Dolejš, Forejt 2019). Zde však analyzujeme samotnou dokumentaci. Porovnáváme mezi sebou tři mapové záznamy (indikační skici, originální mapy, císařské otisky) a jeden písemný (protokol pozemků – *Grund Parzellen Protcoll*). V případě šesti studovaných území se tyto zdroje neshodují až u 7,4 % pozemků. Když se podíváme na prostorové rozmístění těchto neshod, zjistíme, že v některých katastrálních územích se téměř nevyskytují, zatímco v jiných se týkají až 10 % pozemků. To může být způsobeno individuálními chybami mapovatelů nebo heterogenitou krajiny (členitý nebo jednoduchý reliéf, složitá nebo jednoduchá mozaika využití území). Nejvíce neshod mezi čtyřmi zdroji bylo 1) v tom, že určitá kultura využití není rozlišitelná ve všech zdrojích (212 pozemků), 2) jeden nebo dva zdroje zaznamenávají jinou kulturu využití území (113 pozemků) – zde je zajímavé, že nejméně neshod tohoto typu je mezi písemným operátem a indikačními skicami - a 3) pozemek není zaznamenán ve všech zdrojích (79 pozemků). U prvního typu neshod se jedná z velké části o nejednotné označování druhů lesů nebo specifické případy (některé zdroje nerozlišují ornou půdu střídající se s pastvinou, císařské otisky nerozlišují křoviny). Ve třetím případě se jedná nejvíce o malé pozemky, které byly nakresleny do mapy, ale později se patrně zjistilo, že nesplňují kritérium o rozloze pozemku (v přepočtu alespoň 90 m^2) a již se neobjevují v písemném operátu. Jedná se tedy často o zeleninové zahrady, malé pastviny a domy.

Zde nás ovšem zajímají ty neshody mezi zdroji, kdy je v určitém zdroji zaznamenaná jiná kultura využití půdy než v ostatních zdrojích. Je to z velké části případ pastvin s užitkovým dřívím nebo s ovocnými dřevinami (pastevní sady). Druhý nejčastější případ jsou pole s ovocnými stromy. Oba tyto případy jsou vlastně agrolesnické způsoby využití půdy (pouze 91,2 % agrolesnických pozemků se shodovalo v evidenci ve čtyřech sledovaných zdrojích). Tento typ neshod může být u agrolesnictví tak častý proto, že 1) výskyt stromů nebyl pro zpracovatele katastru důležitý, 2) je určení agrolesnické plochy kontroverzní – pro někoho, kdo se podílel na určování kultur, se již jednalo o plochu se stromy, zatímco pro jiného byly stromy zanedbatelné. Agrolesnictví zahrnuje kontinuum krajinného pokryvu mezi pěstováním plodin, stromů a chovem dobytka (den Herder et al. 2015). Ukázalo se, že nejvěrohodnějším mapovým zdrojem Františkovského katastru pro studium využití území jsou indikační skici, naopak nejméně věrohodné jsou císařské otisky. To platí zvláště pro agrolesnické kategorie, protože tyto jsou v císařských otiscích podhodnoceny, ačkoli jsou pro jejich studium často používány (Forejt et al. 2017; Vojta, Drhovská 2012; Pereponova, Skaloš 2019). V jednom případě je to jinak – zatímco ostatní zdroje označují určité pozemky kulturou křoviny (*Gestrippe*), na císařských otiscích je použit symbol pro pastviny s užitkovým dřívím.

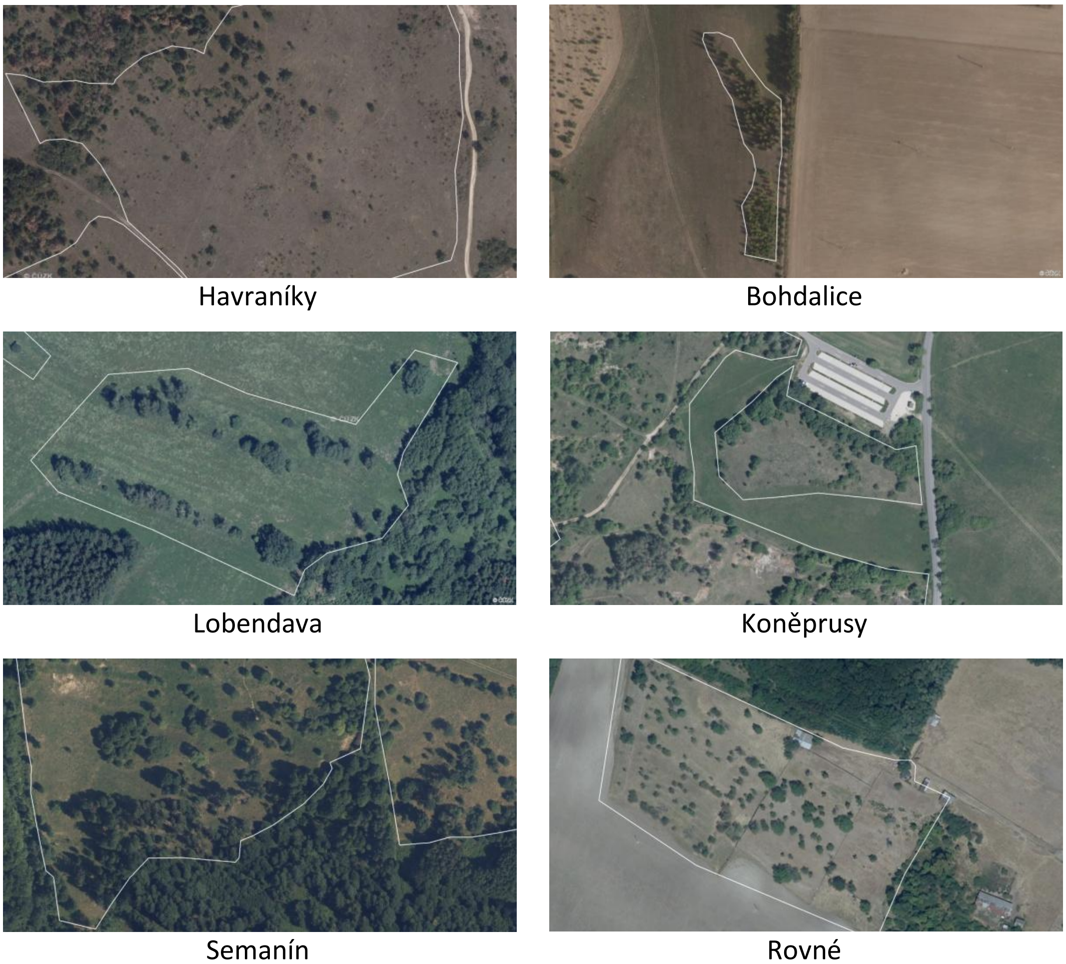
Naše výsledky nelze jednoduše zobecnit na celé území tehdejšího Rakouska. Jedná se o případovou studii na šesti katastrálních územích. Jen v Česku bylo v době tvorby Františkovského katastru více než 13 000 katastrálních území (Bičík, Jeleček, Štěpánek 2001).

6.2 Komentář ke kapitole č. 4: Changes and continuity of wood-pastures in the lowland landscape in Czechia

Tato studie je typickou multitemporální analýzou vývoje krajiny. Sledujeme osud pastvin s dřevinami (*wood pastures*) v krajině nížin a pahorkatin Česka na příkladu 10 katastrálních území. Ty, které jsou v polovině 19. století zaznamenány na Františkovském katastru, byly většinou v dlouhodobém hledisku přeměněny v les nebo zarostly sekundárním lesem. Naopak současné pastviny s dřevinami vznikly zarůstáním otevřených, bezlesých ploch. Můžeme na nich tedy očekávat spíše mladší dřeviny. Oba tyto jevy lze označit za extenzifikaci využívání krajiny. Kontinuálně existující, tedy perzistentní pastviny se starými stromy, se v nižších polohách Česka vyskytují velmi málo. Zajímavé je, že ve srovnání rozloh pastvin s dřevinami v polovině 19. století a let 2015/16 vychází rozloha tohoto biotopu v nové době více než dvakrát větší než v minulosti. Rozhodně to tedy není tak, že by se v Česku nenacházely pastviny s dřevinami (Hartel, Plieninger, Varga 2015).

Tato studie trpí podobným nedostatkem jako jiné multitemporální analýzy – označujeme-li dnes něco jako pastvinu s dřevinami, mluvíme zcela jistě o něčem trochu jiném než je “pastvina s užitkovým dřívím” ve Františkovském katastru, protože současné sociální, kulturní a ekonomické podmínky jsou odlišné od minulosti. Navíc, jistě i mnohé plochy, označované v polovině 19. století za lesy, byly spásány, zvláště tzv. nízké lesy měly určitě z velké části silvopastorální (agrolesnické) využití (Szabó 2010). Takto by se rozšířily i rozlohy agrolesnictví podle Krčmářové (2015). Dalším výrazným nedostatkem této práce je, že nebyl použit náhodný výběr studovaných katastrálních území, tím pádem není možné výsledky příliš zobecňovat. Lze je brát pouze jako případovou studii. V případě, kdy nebyl použit náhodný výběr, by bylo vhodné se důkladně zaměřit na několik území položených blízko sebe a ty rozebrat i s důrazem na místní přírodní a socioekonomické podmínky.

Pastviny s dřevinami jsme v současnosti vymezovali jako spásané plochy, s alespoň 7 stromy/ha a maximálně 80% zápojem korun. Plošně takto charakterizovanou krajinnou jednotku není jednoduché vymezit (Nair, Kumar, Nair 2009). Hustota porostu přeci jen není homogenní po celé pastvině. Na pastvině se mohou vyskytovat dřevinné porosty bez travního podrostu. Jsou *wood pastures* holé pastviny (opuštěná pole) s pruhy spásaných remízků, což je celkem obvyklá situace v Česku? Těžko lze také vymezit jako pastvinu s dřevinami dřevinné porosty bez travního podrostu i bez znaků okusu stromů. Naopak husté dřevinné porosty s více než 80% zápojem mohou mít spásaný travní podrost (Obr. 1).



Obr. 1: Příklady vymezení pastvin s dřevinami v práci Forejt et al. (2017).

Havraníky: Vymezení pastviny na Havranickém vřesovišti převzaté od NP Podyjí.

Bohdalice: Dřevinný porost na jedné části větší pastviny.

Lobendava: Spásaná bývalá pole ohraničená mezemi porostlými dřevinami. Do pastviny s dřevinami zahrnuta i plocha mezi řadami stromů.

Koněprusy: Mezi pastviny s dřevinami není zahrnuta plocha mezi dvěma plochami s dřevinami.

Semanín: Hustý porost, ač se znaky pobytu dobytka, nezařazen do pastviny s dřevinami, protože má zřetelně více než 80% zápoj korun.

Rovné: Pastevní sad vymezený na SV podle oplocení, ačkoli stromy zde takřka nejsou.

6.3 Komentář ke kapitole č. 5: The current status of orchard meadows in Central Europe: Multi-source area estimation in Saxony (Germany) and the Czech Republic

V této studii jsme se pokusili odhadnout rozlohu lučních sadů v Česku a Sasku. Použili jsme k tomu celou řadu geodat. V Česku jsme využili data o půdních blocích dotačního titulu „krajinotvorný sad“ a vlastní mapování v náhodných čtvercích. V Sasku jsme použili výsledky hned tří mapování krajiny, která vymezují kategorii luční sad (*Streuobstwiese*) – BTLNK (mapování typů biotopů a využití půdy v Sasku), SBK2 (druhý běh mapování vybraných biotopů) a ATKIS (německý digitální topografický model). Jako referenci jsme v Česku, Německu, Polsku, Slovensku, Maďarsku a Rakousku použili databázi LUCAS (Eurostat 2015) a dále jsme pomocí fotografií obsažených v této databázi interpretovali rozlohy lučních sadů v kontextu střední Evropy. Podle výsledků jsou v Česku (0,55 % - 0,72 % rozlohy území) luční sady o něco více zastoupeny než v Sasku (0,09 % - 0,54 % rozlohy území). V kontextu střední Evropy jsou luční sady nejhojnější na Slovensku a v jihozápadním Německu.

Tento česko-saský výzkum má několik důležitých přínosů. Jednak představuje revizi odhadů rozlohy lučních sadů ve střední Evropě (Herzog 1998). Dále jsme zjistili, že luční sady v obou zemích nejsou pokryty dotačními systémy. V neposlední řadě je zajímavé, že v současné době často používaná databáze LUCAS (den Herder et al. 2017; Plieninger et al. 2015a) patrně nadhodnocuje takové způsoby využití půdy, které jsou lokalizovány v blízkosti sídel.

Náš výzkum dále ukázal, že metoda den Herdera et al. (2017) nezahrnuje všechny agrolesnické sady, protože např. pro Česko odhadují 0,1 % rozlohy pastevních a polních kultur s ovocnými a jinými stromy s vysokou hodnotou (vše v Česku mají být pastevní sady). Pokud ovšem překontrolujeme fotografie všech bodů s ovocnými stromy v Česku v databázi LUCAS, zjistíme, že na 0,72 % ze všech bodů v Česku je agrolesnická kultura s ovocnými stromy a travním porostem. Přitom jako sekundární krajinný pokryv nemusí být v databázi LUCAS travní porost vyplněn. Na druhou stranu ne všechny body s ovocnými stromy a zároveň travním porostem jsou lučními sady (může jít např. o jediný strom na louce, intenzivní nízkokmenné sady).

Ze srovnání třech mapování krajiny v Sasku plyne, že jen 7 % zmapovaných lučních sadů se objevuje ve všech třech mapováních zároveň. U BTLNK a SBK2 tvoří více než polovinu rozlohy lučních sadů ty, které jsou unikátní (neobjevují se v ostatních dvou mapováních). Zatímco u SBK2 jsou luční sady více reprezentovány ve východním Sasku, BTLNK si jich všímá víc ve středním a západním Sasku. To může být částečně vysvětleno časovým rozpětím vyhotovení těchto tří mapování, částečně odlišnou metodou (BTLNK a ATKIS používají pouze letecké snímky, zatímco SBK2 i terénní mapování). Hlavním důvodem však může být přechodný charakter lučních sadů, jejichž definiční hranice vzhledem k zahradám, intenzivním sadům, nízkokmenným sadům, sadům s vysokou hustotou porostu, porostům s ovocnými i neovocnými stromy atd. je diskutabilní (viz Fig 2 v kap. č. 5, Obr. 2). Přesto jsou v Sasku luční sady (*Streuobstwiesen*) chráněnými biotopy podle zákona o ochraně přírody (Göttlicher 1999).

Obr. 2: Vymezení lučních sadů (Streuobstwiese) na dvou případech v Sasku podle třech mapování krajiny (SBK2, BTLNK, ATKIS). Reálných změn v krajině je málo (nanejvýš řídnou porosty), ale vymezení se liší. Zdroje: LfULG (2005; 2002); GeoSN (2016)

6.4 Souhrnná diskuze

Ve všech třech článcích, z nichž se skládá tato práce, je k agrolesnictví přistupováno jako k prvku reprezentovanému v mapách nebo v prostorových databázích plochami. Na Františkovském katastru jsou všechny typy agrolesnictví označeny jako plošně ohraničené parcely (Forejt et al. 2017; 2020; Krčmářová 2016; 2015). Jako plošné krajinné segmenty jsme vymezovali v mapování současné krajiny pastviny s dřevinami (Forejt et al. 2017) i luční sady (Forejt, Syrbe 2019). Luční sady jsou vymezeny jako plošné biotopy ve třech mapováních využití půdy a biotopů v Sasku (v případě SBK2 i jako mozaiky biotopů) (Forejt, Syrbe 2019). Luční sady (*Streuobstwiesen*) jsou přímo definovány jako plošné biotopy o rozloze minimálně 500 m^2 v komentáři k saskému zákonu o ochraně přírody, jímž jsou luční sady v Sasku chráněny (Göttlicher 1999).

Přístupy v této práci jsou podobné případovým studiím, které vymezují agrolesnictví v krajině jako plochy na základě hustoty porostu (A. pastviny s dřevinami ve Středomoří obvykle jako krajinné segmenty <5 stromů/ha, někdy maximálně 80 stromů/ha - Plieninger 2006; Costa et al. 2011; Schaich et al. 2015; B. pastviny s dřevinami v italských Alpách podle zápoje korun 10 % - 30 % - Garbarino et al. 2011; C. luční sady v Německu jako travní porosty s 20 – 100 stromy/ha - Plieninger et al. 2015b, D. naše studie jako porosty s hustotou alespoň 7 stromů/ha, nanejvýš 80% zápoj korun Forejt et al. 2017). Podobně jako v naší studii bylo agrolesnictví plošně vymezováno na podkladu starých map velkého měřítka v jiných studiích (Agnoletti 2007; Krčmářová 2015; 2016; Vojta, Drhovská 2012; Pereponova, Skaloš 2019; Szabó, Hédl 2013). Všechny tyto přístupy vymezují agrolesnické plošky, tedy v souladu s konceptem ploška – koridor – matrice (Forman, Godron 1986). Jiný přístup je identifikace jednotlivých prvků nelesní dřevinné vegetace, ať už na základě leteckých snímků (Novotný, Skaloš, Plieninger 2017; Demková, Lipský 2015; Plieninger et al. 2012) nebo starých map (Skaloš, Engstová 2010; Skaloš et al. 2015; Plieninger 2012; Varga et al. 2015). Tyto dřevinné prvky (např. solitérní stromy, aleje, remízky) mohou, ale nemusí být součástí agrolesnických systémů. V některých oblastech, např. ve Schwarzwaldu v jihozápadním Německu (Bieling, Konold 2014), se dá těžko rozlišit hranice mezi lesem a pastvinou, protože se jednotlivá využití území prolínají.

Některé referenční výzkumy, v nichž bylo mapováno agrolesnictví, vůbec nezahrnují terénní mapování. Platí to zejména pro mapování dubových pastvin *dehesa* a *montado* na jihozápadě Iberského poloostrova (Costa et al. 2011; Plieninger 2006) a lučních sadů v jihozápadním Německu (Plieninger et al. 2015b). To jsou oblasti, pro které jsou dubové pastviny, resp. luční sady, typické. Tyto prvky mají typickou texturu na leteckém nebo družicovém snímku (Forejt, Syrbe 2019; den Herder et al. 2017), takže není nezbytné verifikovat v terénu, zda je prvek správně určen. Bunce, Pérez-Soba, Smith (2008) nicméně považují za nutné provádět při mapování agrolesnických ploch i terénní průzkumy. V případě dubových pastvin v Řecku (Schaich et al. 2015) nebo modřínových pastvin v Alpách (Garbarino et al. 2011) byla interpretace z leteckých snímků alespoň vzorkově ověřována v terénu. Náš výzkum pastvin s dřevinami byl podpořen terénním mapováním, vlastní mapování lučních sadů však bylo vedeno převážně digitalizací leteckých snímků. Vhodnější by bylo luční sady v Česku vzorkově verifikovat v terénu. U pastvin s dřevinami by navíc v českém kontextu stálo za to vzít v úvahu nejen aktuální situaci – tedy, že se na pozemku pase – ale i dlouhodobější aspekt. Těžko např. považovat za pastvinu pozemek, kde se pase jeden rok (Mládek et al. 2006). To lze ověřovat podle vegetace nebo rozhovory s uživateli pozemku.

Jak ukazují dvě zde uvedené studie, v mapování agrolesnictví se objevují nesourodosti. Na příkladu procesu tvorby Františkovského katastru jsme ukázali, že v různých zdrojích není zaznamenán výskyt stromů na zemědělské půdě, nebo naopak jsou stromy do mapy zaneseny, ačkoli podle písemných podkladů se tam nevyskytují (Forejt et al. 2020). V novodobých mapových dílech v Sasku nepanuje shoda, zda a jak agrolesnickou plochu – zde luční sad – vymezit (Forejt, Syrbe 2019). Určit prostorovou hranici agrolesnické plochy je ovšem složité, protože, jak poznamenávají Nair et al. (2009), neexistují postupy, jak vymezit oblast ovlivněnou stromy. Další možností než jako plochu ovlivněnou stromy by bylo vést hranici agrolesnictví po okraji korun stromů, jež ještě považujeme za součást agrolesnické plochy, případně po hranici pozemku. Jako doplnění k plošnému vymezení agrolesnictví se jeví charakterizovat strukturu vegetace záznamem jednotlivých stromů nebo zápoje korun (le Polain de Waroux, Lambin 2012; Plieninger, Schaar 2008; Schaich et al. 2015). Tento jev je možné sledovat i v čase. Zde se ovšem objevuje problematičnost kombinování různých typů zdrojů - starých map a leteckých snímků, jako například ve studii Forejta et al. (2017). Mapy neumožňují identifikovat jednotlivé dřeviny, natož jejich koruny nebo prostorovou distribuci.

Jiný přístup pro odhad rozlohy agrolesnictví je používán v poslední době, a to odhad pomocí bodové databáze LUCAS (Eurostat 2015). V tomto projektu je zaznamenáváno pro jednotlivé body v kvazi-pravidelném gridu více než 40 atributů o krajinném pokryvu a využití půdy v okolí 20 m kolem bodu. Pomocí kombinace atributů o zemědělských způsobech využití půdy a dřevinném krajinném pokryvu je možno odhadnout rozlohy agrolesnictví v Evropě. Ukazuje se však, že automatickou kombinací atributů o využití půdy a krajinném pokryvu (např. den Herder et al. 2017) nezískáme všechny agrolesnické plochy (Forejt, Syrbe 2019). Pomocí tohoto přístupu nejsme schopní získat prostorové vymezení agrolesnických ploch. Z těchto dat je však možné získat indikátory pro využití půdy v Evropské unii. Náš přístup pro odhad rozlohy lučních sadů ve střední Evropě však kombinoval bodový přístup s plošným, protože jsme brali v úvahu minimální rozlohu travních porostů s ovocnými stromy podle komentáře k saskému zákonu o ochraně přírody – 500 m^2 (Göttlicher 1999). Jiným přístupem ke kvantifikaci významu agrolesnictví by mohla být vzdálenost k nejbližší dřevině od náhodně umístěných bodů nebo počet a velikost dřevin ve vzdálenosti od náhodně umístěného bodu. LUCAS (Eurostat 2015) udává, že buď je, nebo není přítomna dřevina. Námi navržený přístup by přistupoval k agrolesnictví jako ke kontinuu (Manning, Lindenmayer, Nix 2004; den Herder et al. 2015).

Většina uvedených prací mapující agrolesnictví k němu přistupují v užším pojetí. Neberou v úvahu např. lesy, v nichž se sbírají lesní plody a houby, pastvu sobů v tundře ani oborní chov zvěře, což patří také mezi agrolesnické praktiky. Navíc, vlastně téměř všem těmto přístupům lze vytknout, že k agrolesnictví přistupují jako k pouhé kombinaci zemědělství a stromů. V agrolesnictví jsou však důležité interakce mezi zemědělskou činností, stromy a lidmi (Sinclair 1999).

Přes limity přístupů, jež jsme použili v uvedených článcích, můžeme konstatovat, že agrolesnictví bylo i je významným využitím krajiny Česka. Význam agrolesnictví v polovině 19. století velice dobře zdokumentovala Krčmářová (2015; Krčmářová & Jeleček 2017). Srovnáme-li její výsledky s našimi, zjistíme, že význam agrolesnictví vyjádřený rozlohou se v Česku od poloviny 19. století patrně významně nesnížil. Podle jejích studií bylo průměrné zastoupení agrolesnictví v katastrálních obcích Čech 2,4 % rozlohy, z toho pastviny s užitkem dřeva 1,4 %, pastviny s ovocnými stromy 0,18 % a louky s ovocnými stromy 0,14 % (dohromady tedy 0,32 % travních porostů s ovocnými stromy – lučních sadů). Podle našich studií zaujímaly pastviny s dřevinami v devíti katastrálních územích v nížinách Česka v současnosti 1,7 % rozlohy (Forejt et al. 2017) a luční sady 0,55 % až 0,72 % rozlohy Česka (Forejt, Syrbe 2019). V jiné studii bylo zmapováno 30 katastrálních území Česka, v nichž mají pastviny s dřevinami zastoupení dokonce 4,7 % rozlohy (Pereponova, Skaloš 2019).

Taková rozloha agrolesnictví Česku zajišťuje celou řadu ekosystémových služeb, například retenci vody (Ghaley, Vesterdal, Porter 2014), snižování eroze (Palma et al. 2007), ukládání uhlíku (Hernández-Morcillo et al. 2018; Mosquera-Losada et al. 2018b), bránění pronikání dusíku do podzemních vod, zvyšování biodiverzity zemědělské krajiny (Horák 2014; Hartel et al. 2014; Gallé et al. 2017; Dorresteijn et al. 2013; Kajtoch 2017), pozitivní působení na estetickou hodnotu krajiny (Pinto-Correia et al. 2011; Surová, Pinto-Correia, Marušák 2014), zvyšování rekreačního potenciálu zemědělské krajiny (Ohnesorge et al. 2015). Z některých těchto důvodů stromy pozitivně hodnotí na svých pozemcích i zemědělci (Hartel, Réti, Craioveanu 2017; Blanco et al. 2020; Rois-Díaz et al. 2018; García de Jalón et al. 2017). Proto je s podivem, že agrolesnictví nedostává dostatečnou podporu v rámci společné zemědělské politiky EU, ba dokonce společná zemědělská politika donedávna kladla agrolesnictví překážky (Beaufoy 2014; Beaufoy et al. 2015; Mosquera-Losada et al. 2018a), takže někteří zemědělci kvůli tomu stromy na svých pozemcích káceli (Jakobsson, Lindborg 2015; Sandberg, Jakobsson 2018).

6.5 Témata pro budoucí výzkum agrolesnictví v Česku

Jak bylo zmíněno výše, ne každý strom na zemědělské půdě je vhodné označovat jako agrolesnictví (Sinclair 1999). Jaké jsou praktiky využívání stromů zemědělci, případně jaký je vztah dalších stakeholderů ke dřevinám na zemědělské půdě, jsou důležité otázky pro další výzkum agrolesnictví v Česku. Tyto otázky je důležité zodpovědět pro různé typy agrolesnictví i pro různé regiony. Luční nebo polní sady poskytují ovoce, které ovšem často zůstává ležet pod stromy, takže tato ekosystémová služba je nevyužita. Někteří zemědělci jistě využívají pastviny, respektive louky s dřevinami pro získávání palivového dříví. Ceněný je stín jako úkryt před sluncem pro pasoucí se dobytek. Menší část hospodářů si dřevin patrně cení jako biotopu živočichů, případně je na svých pozemcích ponechávají, protože to tak dělali jejich předci. Důležitá je historie pozemků z pohledu zemědělců, která by pravděpodobně vysvětlila motivace pro pěstování dřevin na pozemku. U dřevin na silvoorebních systémech s cenným dřevem (např. třešní ptačí), které se v Česku téměř nevyskytují, se pravděpodobně počítá se zhodnocením v dlouhodobém horizontu. Rychle rostoucí dřeviny s dobou obmýtí několika let, jsou v Česku převážně zastoupeny jako uniformní kultury, zřídka jako agrolesnická praktika, např. při chovu drůbeže (Kotrba 2014). Možná i u nás někdo tajně pase v lese jako v Maďarsku (Varga et al. 2016), kde to bylo donedávna zakázané stejně jako v Česku (Varga et al. 2020). Toto vše je vhodné ověřit i u nás.

V případě agrolesnických praktik je dále nutné charakterizovat vegetační strukturu dřevinných porostů, podobně jako byly charakterizovány pastviny s dřevinami v Evropě (Roellig et al. 2018; Bergmeier, Petermann, Schröder 2010). Jaké vegetační typy jsou v českém agrolesnictví zastoupeny? Předběžně tušíme, že v horských pastvinách jsou hlavně kleny, smrky a jeřáby, v nižších polohách jsou typické duby, břízy a borovice (Pereponova, Skaloš 2019). Jak se liší dřevinná vegetace v lesích a na zemědělských plochách? Jaká je prostorová distribuce dřevin na pozemcích? Pravidelná, v pásech, podél vodních toků nebo ve shlucích? Jaká je druhová diverzita dřevin v lučních sadech v různých regionech? Dochází v českém agrolesnictví k zarůstání (Plieninger 2006), umělé obnově nebo k poškozování dřevin (López-Sánchez et al. 2020)? Jsou v českém agrolesnictví problémem invazní rostliny a jak se s nimi zemědělci vyrovnávají? Jsou na agrolesnických plochách staré stromy a mrtvé dřevo jako na pastvinách s dřevinami v Rumunsku nebo v Británii (Falk 2014; Butler, Alexander, Green 2002; Hartel et al. 2013)? Jaká je adaptabilita dřevinných porostů na zemědělských plochách na změnu klimatu v porovnání s českými lesy?

Kromě toho je důležité pomocí institucionální analýzy identifikovat překážky pro větší zavedení agrolesnictví. Je to neochota zemědělců? Jedná se o krácení dotací kvůli výskytu stromů, které jsou znakem nezpůsobilosti pro Státní zemědělský intervenční fond (Sandberg, Jakobsson 2018)? Jaká je úloha přístupu jednotlivých úředníků Státního zemědělského intervenčního fondu? Netvoří zbytečné překážky Státní pozemkový fond při výsadbách stromů? Jedná se o překážky přímo v legislativě? Jak velká, přehledná a administrativně náročná je podpora výsadby stromů na zemědělské půdě? Jak efektivní jsou podpořené výsadby a jaká je jejich udržitelnost?

Jako dobrý prostředek představení ekosystémových služeb by mohly sloužit demonstrační agrolesnické farmy (několik jich již existuje), protože zemědělci a úředníci musí vidět, že se agrolesnictví vyplatí z environmentálních i ekonomických důvodů. Takové farmy provozované jak výzkumnými institucemi a univerzitami, tak neziskovkovými organizacemi a soukromými zemědělci, by mohly být umístěny ve všech krajích Česka, aby byly pro každého zájemce dostupné.

6.6 Shrnutí poznatků disertační práce v bodech

- Agrolesnictví se v Česku vyskytuje. Lučních sadů je 0,55 % - 0,72 % rozlohy Česka (výrazné zastoupení v kontextu střední Evropy). Také se zde vyskytují pastviny s dřevinami, odhad jejich rozlohy u nás však nemáme.
- Rozloha agrolesnictví je v současnosti srovnatelná s jeho rozlohou v 19. století. V minulosti to mohlo být 2 % - 3 % rozlohy Čech. Přesnou evidenci ze současnosti nemáme.
- Vymezit agrolesnickou plochu, a tedy i určit rozlohu agrolesnictví, je problematické, protože nemá jasné hranice.
- Mechanické použití databáze LUCAS pro odhad rozlohy agrolesnictví není zcela spolehlivé.
- Luční sady jsou nejednotně mapovány. Může to být diskutabilní definiční hranicí vzhledem k zahradám, intenzivním sadům, nízkokmenným sadům, sadům s vysokou hustotou porostu, porostům s ovocnými i neovocnými stromy.
- Evidence agrolesnictví na starých katastrálních mapách je nespolehlivá, protože jednotlivé zdroje pozemky evidují často rozdílně. Je nutné používaným zdrojům rozumět. Pro agrolesnictví v polovině 19. století jsou vhodné indikační skici Františkovského katastru.
- Pastviny s dřevinami u nás mají většinou nový původ, vznikly z bezlesých ploch. Nemůžeme tedy na nich očekávat staré stromy.

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