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The loss of farmland trees and shrubs in western Poland in the 21st century assessed with the use of Google Maps

KRZYSZTOF KUJAWA*, KRZYSZTOF JANKU, MOSTEFA MANA AND ADAM CHORYŃSKI

Institute for Agricultural and Forest Environment, Polish Academy of Sciences, Bukowska 19, Poznan, 60-809, Poland
** Corresponding author: krzysztof.kujawa@isrl.poznan.pl, phone: +48 655134253*

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Abstract

With the loss of natural and semi-natural habitats, the diversity and the amount of ecosystem services that can be provided in the agricultural landscape are diminishing, and self-regulatory abilities decrease. The aim of the research (72 sample plots, 1 × 1 km squares, mean time span equal to 8 years) was to recognise the changes in the number and length of woody (tree or shrub) linear landscape elements, and the number of solitary trees in Wielkopolska region to verify how rapid development of agriculture in Poland at the beginning of the 21st century affects the landscape structure. The analyses show a decline by 9.3% (from 2.17 to 1.97 km/km^2) in length of woody linear elements, 7.4% (from 16.5 to 15.0 per km^2) in number of woody linear elements, and 14.6% (from 28.8 to 24.4 per km^2) in solitary trees. The loss was significantly faster in the period (2017–2018) of liberalisation of the regulations on tree and shrub removal, mainly due to a high rate of removal in plots located in residential areas. The decrease in length of woody linear elements occurred in all the categories of their location distinguished in the study (by 9–41% in a category). The highest loss occurred in the woody linear elements located along melioration ditches and water courses, along roads, and in the outskirt of towns. These changes are like those occurred in the 20th century in Western Europe. The decrease in the number of woody linear landscape elements and solitary trees can be considered an indicator of the unsustainable agriculture management.

Keywords: hedgerows, tree alleys, sustainable development, rural landscape, agriculture intensification, law liberalisation, habitat loss

Introduction

Agricultural areas are characterised by a predominance of farmland, a relatively low population density, most often with a high share of people associated with farming, low urbanisation, and dispersed settlement. In Poland, this type of area constitutes more than half (about 60%) of the entire country. Furthermore, farmlands are adjacent to valuable natural areas protected by law, such as nature reserves and national parks. Intensification of agriculture, aimed at reaching higher work efficiency and yield (Matson and Vitousek 2006), results in losses of natural and semi-natural habitats (Diniz-Filho et al. 2009) and strong changes in environmental chemistry, including hydrological conditions. This negative large-scale process is common everywhere in the world where extensive agriculture is transforming into more efficient production systems (Rahman et al. 2018). Expansion of arable lands and their merging, where field margins, woods, ponds, grasslands, wetlands, etc. are eliminated and transformed into arable land cause biodiversity reduction. The reason is not only direct loss of habitats that are crucial for particular species persistence but also positive effect of wooded patches on some species occurring in agroecosystems, e.g., for bumble bees (Diaz-Forero et al. 2011). Simplifying the landscape structure, accompanied by high input of mineral fertilisers and pesticides are threats to the existence of most species of plants, fungi and animals (Hendrickx et al. 2007, Aktar et al. 2009, Gross 2014, Parween and Jan 2019). Moreover, spatial separation of those refuge isolates populations which in the case of linear woody elements limits their role as ecological corridors (Benett 2003, Häkkilä et al. 2017).

With the loss of natural and semi-natural habitats, the diversity and the amount of ecosystem services that can be provided in the agricultural landscape are also diminishing (Wu 2009). As a result, self-regulatory abilities decrease both in terms of functioning of biocenoses and abiotic phenomena and processes (Fu et al. 2013).

The problems of natural resource protection and sustainable use of ecosystem services are in the spotlight of not only scientists, but also political and administrative bodies and representatives of civil society. Especially since it turned out that the conversion of natural ecosystems into arable fields and intensification of agricultural production led to the impoverishment of biodiversity (Bourdeau 2001, Loreau et al. 2002, Donald et al. 2006, Pe'er et al. 2014).

It is widely known that the prerequisite for maintaining a high level of biodiversity and self-regulatory facilities of the agricultural landscape is to preserve the diversified landscape structure (Le Coeur et al. 2002, Marshall and Moonen 2002, Benton et al. 2003). The most important elements here are patches of trees or/and shrubs, the importance of which has long been emphasised and summarised in many studies, both regional and related to specific issues (Wuczyński et al. 2014, Graham et al. 2018), as well as interdisciplinary international syntheses (Marshall and Moonen 2002). They have a positive impact on the water balance, microclimate, mitigation of adverse weather phenomena (droughts, strong winds), improvement of water quality, and increase of biodiversity, constituting breeding or sheltering places for many species. They are also the tool of strengthening biological pest control (Marshall and Moonen 2002). That is why, in crucial legal acts in Poland, i.e., the Act on Nature Conservation (Dz. U. 2004 No. 92 pos. 880), the Act on Environmental Protection (Dz. U. 2001 No. 62 pos. 627) and the Local Government Act (Dz. U. 2018 pos. 994), there are provisions for mid-field wooded patches protection.

Unfortunately, despite their importance, trees and shrubs are still being eliminated in many regions of Europe (Deckers et al. 2005). Poland has become a fast-developing country after entering the EU and rapid changes started taking place in agriculture. It can be illustrated by the 7th place in 2017 and the 3rd in 2018 in real GDP growth rate, exports of agricultural products amounted 27,529 million EUR, GDP growth 4.8%, rural regions gross value added 98,3866 million EUR (26% of total) in 2016 and employment rate in agriculture reached 35% in Poland (Eurostat 2019).

These changes are mainly driven by unsustainable intensification of agricultural production focused on increasing yield, resulting from the use of higher fertilizer doses, as well as from the enlargement of field sizes by merging them and causing decrease in biodiversity including woody vegetation cover which is common for developing countries all over the world (Butchart et al. 2010, Siqueira et al. 2018, Frankl et al. 2019, Malandra 2019). At the same time, the regulations on farmland tree cutting are unstable, which favours elimination of these elements and it often takes place without any control or even monitoring of the state institutions (see e.g., NIK 2018). Based on interviews conducted in 21 municipalities assessed by Karaczun about 1,500,000 trees were cut in Poland in two first months after law liberalisation regarding tree cutting rules (Gurgul 2017). However, no changes in the number of woody linear landscape elements in rural areas have been recognised based on reliable data originated from measurements, so it was not conclusive. Due to the role of shelterbelts and other woody linear landscape elements in the agricultural landscape, their number in the landscape and the dynamics of its changes can be considered as an indicator of sustainable development.

The aim of the research included:

a) recognition of the changes in the number and length of woody linear landscape elements in Wielkopolska region (voivodeship) in the agricultural landscape during the period of rapid economic growth in Poland at the beginning of the 21st century,
b) recognition of the pattern of these changes, i.e., assessment of the dependence of the rate of change on the location of woody linear landscape elements,
c) assessment of the effect of tree cutting regulation liberalisation on the change in the number and length of woody linear landscape elements and in the number of solitary trees.

Materials and methods

Study area

Sample plots were in Wielkopolska region (about 30,000 km^2), where croplands cover 13,790 km^2 (46.2%) and grasslands, 4,765 km^2 (16%) (Eurostat 2017). Agriculture in Wielkopolska region has been intensifying through the 21st century which can be reflected in example by the increase in cereal yield (for grain) by ca. 50% and a strong increase in pesticide use (by 83% in Poland in 2011–2017). At the same time, the number of farms in Wielkopolska region declined by 32% (178,610 to 121,330) and the mean farm area increased by 40% (from 10.5 to 15.0 ha) in 2005–2016 (Eurostat 2019). Wielkopolska region is characterised by intensive agriculture when compared to other regions of Poland and is commonly considered the most important agricultural region of the country. Two classes of farm areas have the biggest share in the total farmed area (excluding special production), that is 10–19.9 ha or 22%, and 100 ha or over ha or 24% (Figure 1). In 2002–2016,

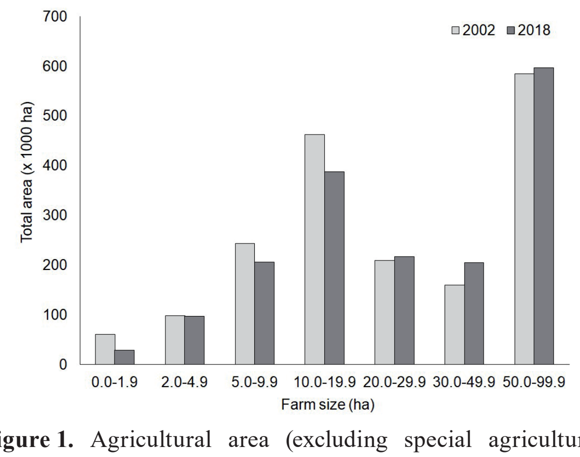

Figure 1. Agricultural area (excluding special agricultural production) in Wielkopolska region in 2002 and 2016 in relation to farm size (Eurostat 2019)

the total area of farms with the size of 0–20 ha has decreased, in contrast to farms of more than 20 ha, whose total area has increased.

Sample plot selection and measurements of studied objects

In establishing the sample plots, a grid of 84 randomly selected 1 × 1 km squares was used. They had been previously selected for the Common Breeding Birds Monitoring (source: State Environmental Monitoring).

Out of these 84 plots in Wielkopolska, as many as 72 plots located in the agricultural landscape were used for the data analysis (see Figure 2). The selected sample plots were divided into agricultural areas where over 80% of area share is arable land (‘field’, N = 41), mixed forest and/or residential areas exceed 20% rate of share (‘mixed’, N = 26) and residential areas, where industrial and residential area constitute more than 20% (‘residential’, N = 5).

The analyses covered woody linear landscape elements (hereafter called ‘tree lines’) and solitary trees growing in agricultural areas, including those adjoining towns or villages. Tree lines (up to several meters wide) were considered separate objects if the distance to the nearest tree line was greater than 10 metres. Each tree line was characterised in terms of location (LLOC) and length (LLEN). According to the location (LLOC), the tree lines were divided into seven categories: growing along roads (‘road’), growing along watercourses (‘wriv’), growing along banks of water reservoirs (‘wres’), growing along melioration ditches (‘ditch’), growing among crop fields (‘field’), growing in the outskirts of the villages (‘vill’) and on the outskirts of the towns (‘town’). The data source for all variables, both numerical (number and length) and categorical (location), were Google Maps with the use of QGIS software. The abundance of tree lines in the individual sample plot was characterised by their number (PL_LNUM) and total length (PL_LLEN).

Analysis of changes in the number of tree lines in a given sample plot was made by comparing the data between the year of the ‘earliest year’ (EYear, Appendix 1), i.e., the earliest year among available in the Google Maps from the period 2000–2018, and the ‘last year’ (LYear, Appendix 1), the latest one available. Both LYear and EYear varied between the sample plots and time span (TIME = LYear – EYear + 1) as well, ranging from two to fourteen years (Table 1). The TIME amounted to 8.0 (95% CI = 0.5) on the average.

As the law regulating tree removal was significantly liberalised since December of 2016 to May of 2017 (approximately in 2017), the time spans were classified into two categories:

1) RLaw (‘restrictive’ law) – time spans that did not cover the year 2017 at all, that is for which LYear < 2017,
2) LLaw (‘liberal’ law) – time spans that covered 2017, that is LYear ≥ 2017.

Therefore, the factorial variable LAW_TYPE (with two levels: RLaw and LLaw) classified the sample plots (with tree lines, and solitary trees) into two groups of objects: managed under restrictive law or managed under liberal law. That classification has enabled quantifying the effect of the liberalisation of the tree cutting regulation on the rate of changes in solitary tree number and tree line number and density.

The liberalisation of the provisions of law concerning tree cutting permits (the Act of 16th December 2016 on amendments to the Act on Nature Conservation, Dz. U. 2016 No. 2249) caused an increase in trees cutting throughout the entire territory of Poland. Therefore, the need to change the law was recognised within next six months. Among others, specifically points regarding the size of trees that can be cut without a permit, inconsistency with other entries, i.e., abolition of the mentioned requirements excluding the species or age of the tree based on municipal decisions, needed to be corrected. This solution

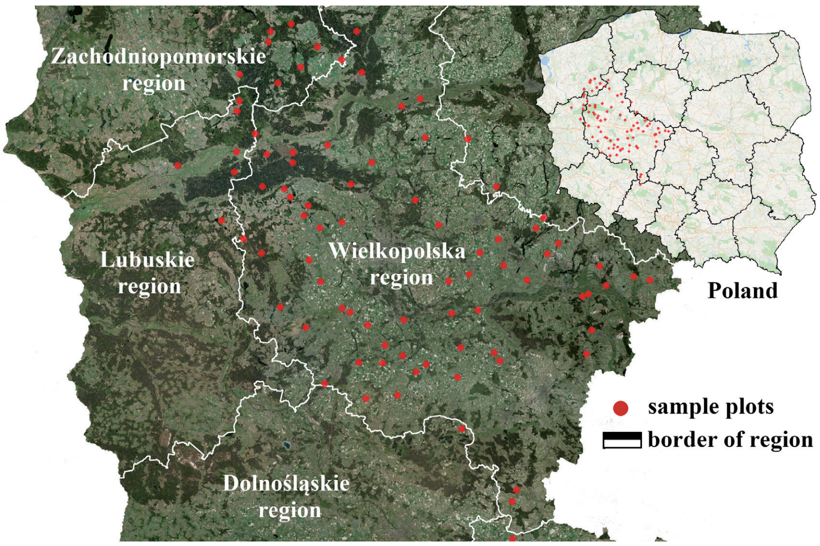

Figure 2. Location of sample plots

Table 1. Frequency (number of sample plots) of time span lengths covered by the analyses

	Time span length (years)												
	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of sample plots	1	1	3	11	13	14	22	0	1	2	2	1	1

gave great freedom in obtaining permits without fulfilling the previously mentioned requirements. This can be noted while looking at the content of the articles supplemented by 21, 6 were repealed and 8 paragraphs were rewritten in the following version of the Act on Nature Conservation (the Act of 11 May 2017 on amendments to the Act on Nature Conservation, Dz. U. 2017 No. 1074). New law rebalanced requirements and referred to the management of private forests reducing the risk of fraud. Unfortunately, in case of trees, the loss compensation will take at least one century.

Statistical analysis

The list of explaining variables consisted of:

a) at plot level
PL_TYPE is the landscape type, i.e., 'field', 'mixed' and 'residential' (categorical variable),

b) at tree line level
LLOC is the location of tree line, i.e., 'road', 'wriv', 'wres', 'ditch', 'field', 'vill' and 'town' (categorical variable),

c) concerning the time
TIME is the length of time span (in years) covered by the analyses (TIME = LYear – EYear + 1) (count variable),
LAW_TYPE is the type of law concerning tree removal: restrictive one ('RLaw') or the liberal one ('LLaw'), (categorical variable); basing on these definitions, the sample plots were divided into two categories (RLaw and LLaw), too.

The explained variables were:

LLEN is the length of tree line (numerical variable, in metres),
PL_LLEN is the length of tree lines per plot (numerical variable, in metres),
PL_LNUM is the number of tree lines number per plot (integer variable),
PL_TNUM is the number of solitary trees per plot (integer variable).

The significance of changes in PL_LLEN, PL_LNUM and PL_TNUM was tested with the use of the Wilcoxon matched pairs test (matched by the plot). In the analysis of the relationship between changes in LLEN, LNUM andT-NUM and explanatory variables, the two-way ANOVA was used in which PL_TYPE, LAW_TYPE, and the interaction PL_TYPE×LAW_TYPE were considered factors. The variable TIME was not included as it was not correlated significantly with explained variables ($-0.07 < r < 0.3$ at $0.53 < P < 0.81$). The 2 × 2 *Chi-square* test was used for testing the significance of the difference in proportions. The statistical analysis was performed with the use of Statistica 12 software package (StatSoft 2013).

Results

In the earliest available years (EYear), there were found as many as 1169 tree lines with a total length of 157.3 km, and 2076 solitary trees. Their distribution among the plots was strongly uneven (Table 2).

Pattern of changes in the abundance of tree lines and the number of solitary trees on a regional scale

In the studied plots, the total length of tree lines per plot (PL_LLEN) decreased by 9.3%, that is from 2.17 to 1.97 km ($Z = 3.95$, $P < 0.001$), the number of tree lines per plot (PL_LNUM) by 7.4%, that is from 16.2 to 15.0 ($Z = 3.47$, $P < 0.001$), and the number of solitary trees per plot (PL_TNUM) by 14.6%, from 28.8 to 24.6 ($Z = 4.09$, $P < 0.001$). All the differences were statistically significant according to the Wilcoxon test.

The sample plots, in which a decrease in measured variables was found, prevailed. The total length of tree lines and total number of solitary trees per plot have decreased in about 60% of plots, while the number of tree lines in about 50% of plots. The share of sample plots, where the values of the variables increased, amounted to 15–20%.

The change in PL_LLEN, PL_LNUM and PL_TNUM was affected by the type of plot (PL_TYPE) statistically insignificantly. However, the tree line decrease was significantly higher in the plots under the liberalised law (see "Methods") (Table 3, Figure 3). Moreover, the effect of law type (LAW_TYPE) was modified by the plot type (PL_TYPE) as significant interactions ($P = 0.0008$) between the plot type and law type occurred. Liberalisation of the law significantly affected the decrease in tree line length and number in the plots situated in residential area only (Table 3, Figure 4, 5).

The changes in the individual tree lines length in relation to their location

The analyses covered 1187 tree lines located mostly among fields, along roads, in the outskirts of villages, and along water courses (Table 4). Out of that number, 534 tree lines were in the plots classified as being under the restrictive tree cutting law (RLaw) and 653 in the plots classified as being under liberal tree cutting law (LLaw). The length

Table 2. Summary statistics for the total length (PL_LLEN) and total number (PL_LNUM) of woody linear landscape elements per plot, and total number of solitary trees per plot (PL_TNUM) in the earliest year of analyses

Variable	N	*Min*	*Max*	*Mean*	*SD*	*Median*	Lower Quart.	Upper Quart.
PL_LLEN	72	0.0	10804.0	2170.8	2005.4	1557.5	854.0	2778.0
PL_LNUM	72	0.0	104.0	24.1	20.1	19.0	9.0	34.0
PL_TNUM	72	0.0	137.0	28.8	25.8	20.5	10.0	35.5

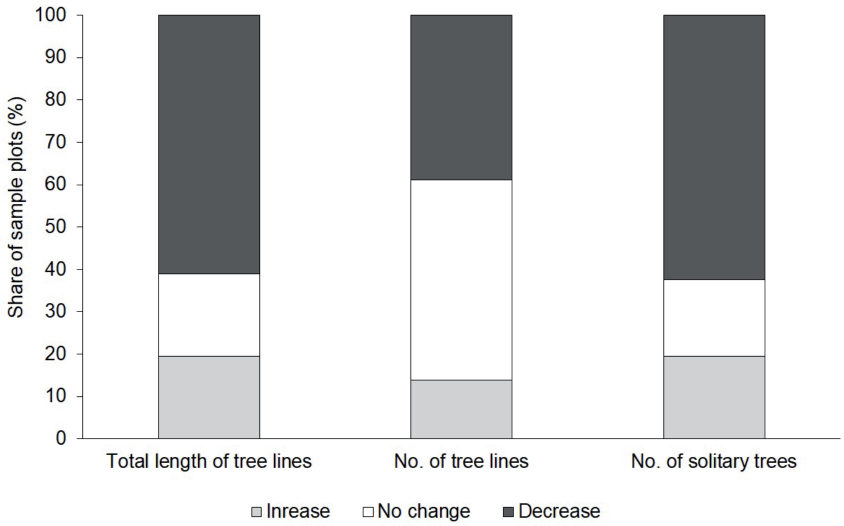

Figure 3. The share (%) of sample plots with increasing, stable and decreasing amount of tree lines and solitary trees

Table 3. Effect of plot type ('field' vs. 'mixed' vs. 'residential') and tree cutting law type ('restrictive' vs. 'liberal') on the changes in length of woody linear landscape elements per plot (PL_LLEN), number of woody linear landscape elements per plot (PL_TNUM), and number of solitary trees per plot (PL_TNUM) analysed with the aid of multivariate ANOVA

Factor	*Df*	PL_LLEN		PL_LNUM		PL_TNUM	
		F	*P*	*F*	*P*	*F*	*P*
Const	1	6.1	0.0161	9.7	0.0028	6.6	0.0127
Plot type (PL_TYPE)	2	0.7	0.5045	0.7	0.5092	0.1	0.9217
Tree cutting law (LAW_TYPE)	1	11.3	0.0013	6.7	0.0117	0.4	0.5287
PL_TYPE x LAW_TYPE	2	7.9	0.0008	3.7	0.0298	0.7	0.4895

Figure 4. Effect of tree cutting law type on the changes in tree line length per plot (a), in tree line number per plot (b), and in solitary tree number per plot (c)

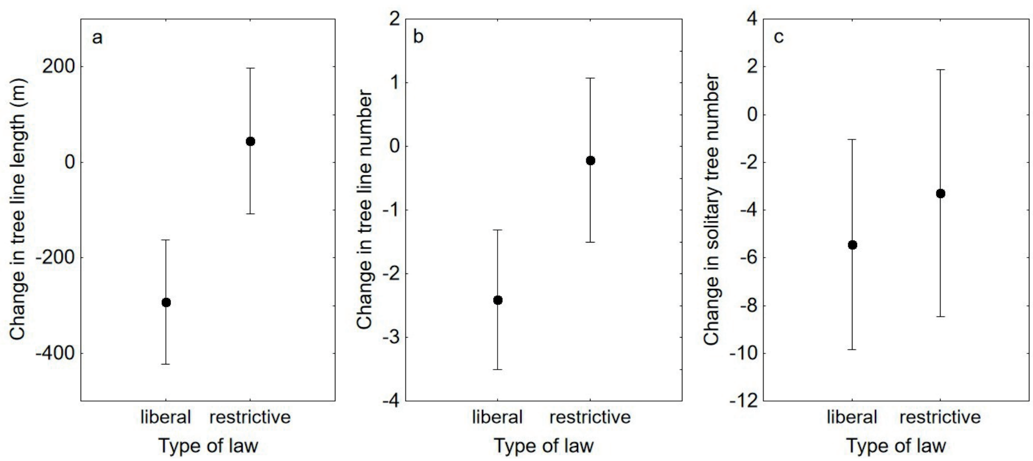

Figure 5. Effect of the interaction between the tree cutting law type and plot type on the changes in tree line length per plot (a), in tree line number per plot (b), and in solitary tree number per plot (c)

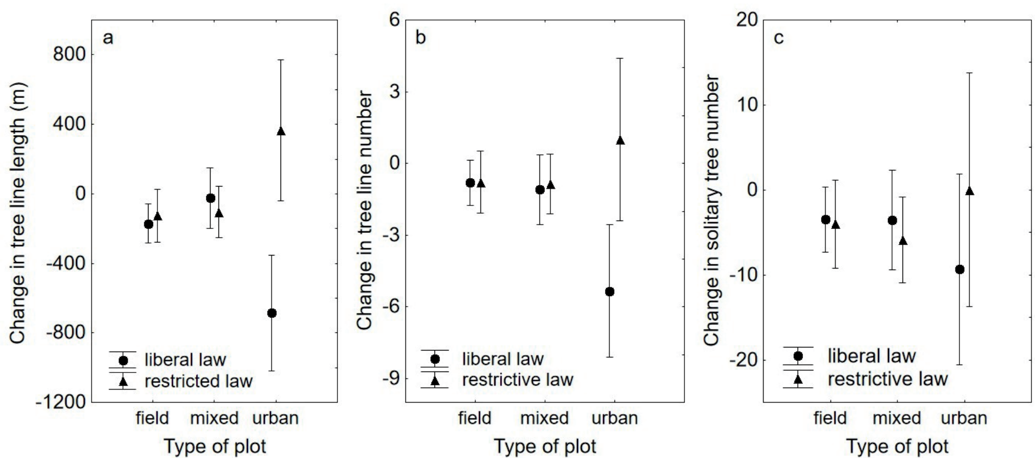

Table 4. Location of the analysed woody linear landscape elements

Location	N	%
Among fields (field)	675	56.9
Along roads (road)	180	15.2
Outskirts of the villages (vill)	152	12.8
Along water courses (wriv)	85	7.2
Outskirts of towns (towns)	41	3.5
Along melioration ditches (ditch)	34	2.9
Riparian – at water bodies (wres)	20	1.7

Table 5. Frequency distribution of woody linear landscape elements length in the earliest year covered by the analysis

Range	N	%
0 ≤ x < 200	958	80.7
200 ≤ x < 400	149	12.6
400 ≤ x < 600	52	4.4
600 ≤ x < 800	18	1.5
800 ≤ x < 1000	7	0.6
1000 ≤ x < 1200	2	0.2
1200 ≤ x < 1400	1	0.1

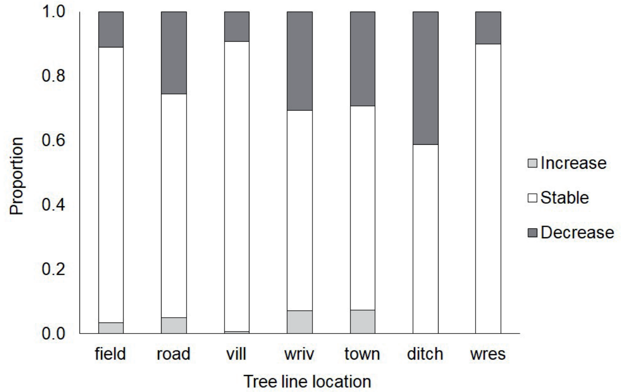

Figure 6. The share (%) of tree lines, which length increased, remained stable, and decreased, in relation to their location

Field – among crop fields, road – along roads, vill – on outskirts of villages, wriv – along watercourses, towns – on outskirts of towns, ditch – along melioration ditches, wres – along banks of water reservoirs.

(LLEN) of 93% tree lines ranged between 6 (minimum value) and 400 metres (Table 5).

The LLEN changed in 19.4% ($N = 230$) of tree lines. It decreased in 15.8% ($N = 188$) and increased in 3.5% ($N = 42$) of tree lines. The increase has not been detected in two categories of the tree lines: those located at water reservoirs and those located along melioration ditches and occurred in up to 7% of tree lines of a given category (Figure 6). The decrease in the LLEN occurred in all the categories distinguished in the study, in 9–41% of tree lines from a given category. Thus, the share of shortened tree lines was much higher than the share of elongated tree lines in all tree line location categories. The highest tree line loss occurred in the category of tree lines located along melioration ditches and water courses, along roads, and in the outskirts of towns (Figure 6).

Among the tree lines occurred in the plots covered by the restrictive regulation on tree cutting (RLaw), a decrease in LLEN occurred in 13.4% (70/452) of tree lines vs. 18.2% (118/529) of tree lines in the plots covered by the liberalised regulation on tree cutting (LLaw). The difference in these proportions was statistically significant in the *Chi-square* test (*Chi-square* = 4.99, $df = 1$, $P = 0.025$).

Discussion

The analyses presented in the paper show a general decline, both in tree line amount (length and number) and solitary tree number in Wielkopolska region. The change is like those occurred in the 20th century in Western Europe. For example, in a study in France between 1952 and 1985, the hedgerow length decreased by ⅓ (Burel and Baudry 1990), in the whole UK between 1984 and 1990 by 23%, on average (Barr and Gillespie 2000), and in Denmark between 1972 and 1995 by 10% but had been preceded by an increase between 1950 and 1972 (Kristensen and Caspersen 2002). Although there have been undertaken some measures to stop the loss of hedgerows (e.g., successful in the UK after 1990, see Cornulier et al. 2011), the declining trend is presumably still present and common, at least in some regions. For example, in central Spain both hedgerow density and the number declined by several percent both in protected and unprotected areas (Arnaiz-Schmitz et al. 2018). Similar situation took place in northern Belgium, where the hedgerow length decreased by 28.2% between 1974 and 2015 (Van Den Berge et al. 2018). The recent decline in tree line amount was also described in North America (Burke et al. 2019). Unfortunately, despite the key role of hedgerows for farmland biodiversity protection and ecosystem services, they have not been systematically monitored until now, neither in Poland, nor in the UE. An outstanding exception is the monitoring scheme in the UK, called “Countryside Survey” (Barr and Gillespie 2000).

Monitoring land use/land cover changes is considered the essential first step to the identification of driving forces responsible for changes that take place in a landscape (Bürgi et al. 2004). Observation of those dynamics is crucial for understanding the complex interactions between social, environmental and geophysical processes. Unfortunately, there is an actual gap in recent reliable data (i.e., within two last decades) on the change in tree line amount in the EU. Therefore, we are not able to compare the changes occurring in Poland with those in other countries.

The observed decline in the studied region of Poland occurred commonly (the hedgerow density and the number of solitary trees – in about 60% sampled plots), thus the tendency of elimination or reduction of the tree lines and solitary trees seems to be common for various regions. Thus, although the positive role of tree lines for landscape functioning is indisputable (Ryszkowski and Bartoszewicz 1996, Baudry et al. 2000, Marshall 2002), their preservation and management are taken into consideration by inhabitants inadequately.

The analyses show that in general, human decisions on tree cutting have not been related to the landscape type per se (Table 5) and were strongly related to tree cutting law type (Table 3, Figures 4 and 5). However, there was a significant interaction between landscape type and law type, detectable despite big differences in sample size between the landscape types (see the section "Sample plot selection…"). The changes in the number of solitary trees and tree lines did not differ between the studied landscape types, especially under restrictive law (Table 3). However, when the law regulating tree cutting was changed in 2017 into more liberal, the consequences of the change strongly differed between the landscape types. The rates of solitary tree or tree line loss were similar in the agricultural and mixed landscapes, while a strong decrease in both tree line length and solitary number occurred in the residential areas. Moreover, under restrictive law, values of the variables listed above increased in the residential areas. That is worth mentioning is the fact that the decline in the tree cover comes together with an increase of impervious cover (Nowak and Greenfield 2018). Inhabitants of residential areas often argue that reducing the number of trees and substituting them with, for example, concrete surfaces is a case of cost reduction. This is false as people are not considering the negative of impervious cover maintenance like poor rainwater management, pollution increase and loss of cooling effect (Livesley et al. 2016). What is more, people rarely associate several societal benefits: pollution removal, carbon sequestration, lower energy demands (production, usage) and lower pollution due to energy production. Nowak and Greenfield (2018) estimated the loss in benefits to society due to losses in tree cover in the United States at about USD 100 million per year. There is an extensive literature on the issue of costs and benefits of trees in the urban areas (see, e.g., Song et al. 2018, Nowak and Greenfield 2012). Usually, more inhabited areas are characterised by stronger pressure to retrieve possible space for potential investments. Therefore, in a conflict between people and nature, and in a situation of simplified legal coverage, trees are the underdog. Furthermore, the Polish legal change has been treated as a "window of opportunity" to undertake actions. Before the new legislation came into force people were discouraged by procedural issues needed to cut a tree, even though it was often only a formality. Liberalisation of the legislation widely covered by the media, both for and against, became a trigger to move on with dealing with trees that were interfering with plans of inhabitants of municipal areas. Moreover, people felt that the liberal law will not last forever. Therefore, it might be the reason for a pike in the number of trees cut after liberal law implementation. Summing up, inhabitants of residential areas reacted stronger to changes in tree cutting law which is presumably related to more intensive conflict about land use and goals in residential area when compared to agricultural or mixed areas. Fortunately, the liberalised law has been changed again to more restrictive due to many protests, public discussions and publications (Kujawa et al. 2018). An issue worth further research would be to estimate losses in tree cover some years later to see whether it has slowed down. The lesson shows that the law regulating relation between humans and nature should be changed very carefully.

Environment and landscape are not only a matter of local, regional or national scale regulations. The development of tools for decision-makers on all decision levels should: 1. recognise and value impacts degrading the environment; 2. assess future sources of danger; 3. develop sustainable land use systems (Piorr 2003). Having in mind that it is easy to cut and harder to grow trees one should expect that people's responses to economic opportunities, as mediated by institutional factors, drive land-cover changes. Opportunities and constraints for new land uses are created by local as well as national markets and policies (Lambin et al. 2001).

The decrease in tree line length also depended strongly on the location of tree lines that determines their functions and the role for humans. The common feature of tree lines, which were most shortened, was their location along linear elements of landscape like roads, melioration ditches and water courses. Presumably, the presence of trees could be considered conflicting to some management goals like providing appropriate roads visibility for drivers and keeping melioration ditches without plant cover for enabling efficient water run-off. This is an example of unbalanced management of linear semi-natural elements in farmland in which some important ecosystem services are omitted or underestimated.

Conclusions

1. The decrease in the number of woody linear landscape elements and solitary trees in Wielkopolska region in Poland is an indicator of currently unsustainable agriculture management. It must be underlined that with the loss of mid-field shelterbelts and other tree lines, a variety of ecosystem services is lost.
2. The legal conditions concerning woody linear landscape elements in an agricultural landscape in Poland do not ensure their protection.
3. The loss of farmland trees (solitary or others) has undergone despite the existence of legal provisions that speak directly about the protection of wooded patches in an agricultural landscape.
4. Many trees are in privately owned areas, for which the right to regulation by local authorities is strongly limited.
5. As the ecological consequences of farmland tree removal are significant and long lasting, the law regulating tree removal should be changed carefully and based on the precautionary principle much stronger.

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References

Aktar, M.W., Sengupta, D. and Chowdhury, A. 2009. Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary Toxicology* 2(1): 1–12. https://doi.org/10.2478/v10102-009-0001-7.

Arnaiz-Schmitz, C., Schmitz, M.F., Herrero-Jáuregui, C., Gutiérrez-Angonese, J., Pineda, F.D. and Montes, C. 2018. Identifying socio-ecological networks in rural-urban gradients: Diagnosis of a changing cultural landscape. *Science of the Total Environment* 612: 625–635. https://doi.org/10.1016/j.scitotenv.2017.08.215.

Barr, C.J. and Gillespie, M.K. 2000. Estimating hedgerow length and pattern characteristics in Great Britain using countryside survey data. *Journal of Environmental Management* 60(1): 23–32. https://doi.org/10.1006/jema.2000.0359.

Baudry, J., Bunce, R.G. and Burel, F. 2000. Hedgerows: an international perspective on their origin, function and management. *Journal of Environmental Economics and Management* 60(1): 7–22. https://doi.org/10.1006/jema.2000.0358.

Bennett, A.F. 2003. Linkages in the Landscape. The Role of Corridors and Connectivity in Wildlife Conservation. School of Ecology and Environment, Deakin University – Melbourne Campus, Burwood, Victoria 3125, Australia, 263 pp.

Bourdeau, P. 2001. Biodiversity. In: Tolba, M.K. (Ed.) Our fragile world. EOLSS Publishers, Oxford, p. 299–308.

Burel, F. and Baudry, J. 1990. Structural dynamic of a hedgerow network landscape in Brittany France. *Landscape Ecology* 4(4): 197– 210. https://doi.org/10.1007/BF00129828.

Bürgi, M., Hersperger, A.M. and Schneeberger, N. 2004. Driving forces of landscape change – current and new directions. *Landscape Ecology* 19(8): 857–868. https://doi.org/10.1007/s10980-005-0245-3.

Burke, M.W., Rundquist, B.C. and Zheng, H. 2019. Detection of Shelterbelt Density Change Using Historic APFO and NAIP Aerial Imagery. *Remote Sensing* 11(3): 218. https://doi.org/10.3390/rs11030218.

Butchart, S., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J., Almond, R., Baillie, J., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.C. and Watson, R. 2010. Global biodiversity: indicators of recent declines. *Science* 328(5982): 1164–1168. https://doi.org/10.1126/science.1187512.

Cornulier, T., Robinson, R.A., Elston, D., Lambin, X., Sutherland, W.J. and Benton, T.G. 2011. Bayesian reconstitution of environmental change from disparate historical records: hedgerow loss and farmland bird declines. *Methods in Ecology and Evolution* 2(1): 86–94. https://doi.org/10.1111/j.2041-210X.2010.00054.x.

Diniz-Filho, J.A.F., Oliveira, G., Lobo, F.C., Guimarães Ferreira, L., Bini, L.M. and Rangel, T. 2009. Agriculture, habitat loss and spatial patterns of human occupation in a biodiversity hotspot. *Scientia Agricola* 66(6): 764–771. https://doi.org/10.1590/S0103-90162009000600007.

Deckers, B., Kerselaers, E., Gulinck, B., Muys, B. and Hermy, M. 2005. Long-term spatio-temporal dynamics of a hedgerow network landscape in Flanders, Belgium. *Environmental Conservation* 32(1): 20–29. https://doi.org/10.1017/S0376892905001840.

Diaz-Forero, I., Kuusemets, V., Mänd, M., Liivamägi, A., Kaart, T. and Luig, J. 2011. Effects of forest habitats on the local abundance of bumblebee species: a landscape-scale study. *Baltic Forestry* 17(2): 235–242.

Donald, P.F., Sanderson, F.J., Burfield, I.J. and Van Bommel, P.J. 2006. Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990–2000. *Agriculture, Ecosystems & Environment* 116 (3-4): 189–196. https://doi.org/10.1016/j.agee.2006.02.007.

Dz. U. 2001. No. 62 pos. 627 Ustawa z dnia 27 kwietnia 2001 r. ochronie przyrody [The Act of 27th April on Nature Consrevation]. Available online at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20010620627 (in Polish).

Dz. U. 2004. No. 92 pos. 880 Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody [The Act of 16th April 2004 on Nature Conservation]. Available online at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20040920880 (in Polish).

Dz. U. 2016. No. 2249 Ustawa z dnia 16 grudnia 2016 r. o zmianie ustawy o ochronie przyrody oraz ustawy o lasach [The Act of 16th December 2016 on amendments to the Act on Nature Conservation]. Available online at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20160002249 (in Polish).

Dz. U. 2017. No. 1074 Ustawa z dnia 11 maja 2017 r. o zmianie ustawy o ochronie przyrody [The Act of 11th May 2017 on amendments to the Act on Nature Conservation]. Available online at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20170001074 (in Polish).

Dz. U. 2018. pos. 994 Ustawa z dnia 8 marca 1990 r. o samorządzie gminnym [The Act of 8th of March 1990 Local Government Act]. Available online at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20180000994 (in Polish).

Eurostat. 2017. Land cover overview by NUTS 2 regions [lan_lcv_ovw] (Last update: 10-07-2017). Available online at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lan_lcv_ovw&lang=en.

Eurostat. 2019. Farm indicators by agricultural area, type of farm, standard output, legal form and NUTS 2 regions [ef_m_farmleg] (Last update: 06-05-2019). Available online at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_m_farmleg&lang=en.

Frankl, A., Nyssen, J., Adgo, E., Wassie, A. and Scull, P. 2019. Can woody vegetation in valley bottoms protect from gully erosion? Insights using remote sensing data (1938-2016) from subhumid NW Ethiopia. *Regional Environmental Change* 19(7): 2055–2068. https://doi.org/10.1007/s10113-019-01533-4.

Fu, B., Wang, S., Su, C. and Forsius, M. 2013. Linking ecosystem processes and ecosystem services. *Current Opinion in Environmental Sustainability* 5(1): 4–10. https://doi.org/org/10.1016/j.cosust.2012.12.002.

Gross, M. 2014. Systemic pesticide concerns extend beyond the bees. *Current Biology* 24(16): 717–720. https://doi.org/10.1016/j.cub.2014.07.071.

Häkkilä, M., Le Tortorec, E., Brotons, L., Rajasärkkä, A., Tornberg, R. and Monkkonen, M. 2017. Degradation in landscape matrix has diverse impacts on diversity in protected areas. *PLoS ONE* 12(9): e0184792. https://doi.org/org/10.1371/journal.pone.0184792.

Hendrickx, F., Maelfait, J.P., Wingerden, W., Schweiger, O., Speelmans, M., Augenstein, I., Billeter, R., Bailey, D., Bukacek, R., Burel, F., Diekötter, T., Dirksen, J., Herzog, F., Liira, J., Roubalova, M., Vandomme, V. and Bugter, R. 2007. How landscape structure, land-use intensity and habitat diversity affect components of total arthropod diversity in agricultural landscapes. *Journal of Applied Ecology* 44(2): 340–351. https://doi.org/10.1111/j.1365-2664.2006.01270.x.

Kristensen, S.P. and Caspersen, O.H. 2002. Analysis of changes in a shelterbelt network landscape in central Jutland, Denmark. *Journal of Environmental Management* 66(2): 171–183. https://doi.org/10.1006/jema.2002.0582.

Kujawa, A., Kujawa, K., Zajączkowski, J., Borek, R., Tyszko-Chmielowiec, P., Chmielowiec-Tyszko, D., Józefczuk, J., Krukowska--Szopa, I., Śliwa, P. and Witkos-Gnach, K. 2018. Zadrzewienia na obszarach wiejskich – dobre praktyki i rekomendacje [Tree lines in rural areas – good practices and recommendations]. Fundacja Eko Rozwoju, Wrocław, Poland, 44 pp. (in Polish). Available online at: https://www.researchgate.net/publication/332290126_Zadrzewienia_na_obszarach_wiejskich_-_dobre_praktyki_i_rekomendacje.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, M.B., Skanes, H., Steffen, W.L., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C. and Xu, C. 2001. The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change* 11(4): 261–269. https://doi.org/10.1016/S0959-3780(01)00007-3.

Livesley, S.J., McPherson, G.M. and Calfapietra, C. 2016. The Urban Forest and Ecosystem Services: Impacts on Urban Water, Heat, and Pollution Cycles at the Tree, Street, and City Scale. *Journal of Environmental Quality* 45(1): 119–124. https://doi.org/10.2134/jeq2015.11.0567.

Loreau, M., Downing, A., Emmerson, M., Gonzalez, A., Hughes, J., Inchausti, P., Joshi, J., Norberg, J. and Sala, O. 2002. A new look at the relationship between diversity and stability. In: Loreau, M., Inchausti, P. and Naeem, S. (Eds.) Biodiversity and ecosystem functioning: synthesis and perspectives. Oxford University Press, Oxford, UK, p. 79–91.

Malandra, F., Vitali, A., Urbinati, C., Weisberg, P. and Garbarino, M. 2019. Patterns and drivers of forest landscape change in the Apennines range, Italy. *Regional Environmental Change* 19(7): 1973–1985. https://doi.org/10.1007/s10113-019-01531-6.

Marshall, E.J.P. 2002. Introducing field margin ecology in Europe. *Agriculture, Ecosystems and Environment* 89(1-2): 1–4. https://doi.org/10.1016/S0167-8809(01)00314-0.

Marshall, E.J.P. and Moonen, A.C. 2002. Field margins in northern Europe: their functions and interactions with agriculture. *Agriculture, Ecosystems and Environment* 89(1-2): 5–21. https://doi.org/10.1016/S0167-8809(01)00315-2.

Matson, P.A. and Vitousek, P.M. 2006. Agricultural Intensification: Will Land Spared from Farming be Land Spared for Nature? *Conservation Biology* 20(3): 709–710. https://doi.org/10.1111/j.1523-1739.2006.00442.x.

NIK. 2018. Wystąpienie Pokontrolne [Post-control speech]. KSI.410.002.08.2018, P/18/046. Najwyższa Izba Kontroli, Departament Środowiska, Warszawa, 29 pp. (in Polish). Available online at: https://www.nik.gov.pl/kontrole/wyniki-kontroli-nik/pobierz,ksi~p_18_046_201806140530561528954256~id7~01,typ,kj.pdf.

Nowak, D.J. and Greenfield, E.J. 2012. Tree and impervious cover change in U.S. cities. *Urban Forestry and Urban Greening* 11(1): 21–30. https://doi.org/1016/j.ufug.2011.11.005.

Nowak, D.J. and Greenfield, E.J. 2018. Declining urban and community tree cover in the United States. *Urban Forestry and Urban Greening* 32: 32–55. https://doi.org/10.1016/j.ufug.2018.03.006.

Parween, T. and Jan, S. 2019. Ecophysiology of Pesticides. Interface between Pesticide Chemistry and Plant Physiology. Academic Press, Cambridge, MA, 332 pp.

Pe'er, G., Dicks, L.V., Visconti, P., Arlettaz, R., Báldi, A., Benton, T.G., Collins, S., Dieterich, M., Gregory, R.D., Hartig, F., Henle, K., Hobson, P.R., Kleijn, D., Neumann, R.K, Robijns, T., Schmidt, J., Shwartz, A., Sutherland, W.J., Turbé, A., Wulf, F. and Scott, A.V. 2014. EU agricultural reform fails on biodiversity. *Science* 344(6188): 1090–1092. https://doi.org/10.1126/science.1253425.

Piorr, H.P. 2003. Environmental policy, agri-environmental indicators and landscape indicators. *Agriculture, Ecosystems and Environment* 98(1-3): 17–33. https://doi.org/10.1016/S0167-8809(03)00069-0.

Rahman, M.M., Islam, M.S. and Pramanik, M.A.T. 2018. Monitoring of changes in woodlots outside forests by multi-temporal Landsat imagery. *iForest* 11(1): 162–70. https://doi.org/10.3832/ifor2021-010.

Ryszkowski, L. and Bartoszewicz, A. 1996. Influence of shelterbelts and meadows on the chemistry of ground water. In: Ryszkowski, L., French, N. and Kedziora, A. (Eds.) Dynamics of an agricultural landscape. PWRiL, Poznan, Poland, p. 98–109.

Siqueira, A., Ricaurte, L.F., Borges, G.A., Nunes, G.M. and Wantzen, K.M. 2018. The role of private rural properties for conserving native vegetation in Brazilian Southern Amazonia. *Regional Environmental Change* 18(1): 21–32. https://doi.org/10.1007/s10113-015-0824-z.

Song, X.P., Tan, P.Y., Edwards, P. and Richards, D. 2018. The economic benefits and costs of trees in urban forest stewardship: A systematic review. *Urban Forestry and Urban Greening* 29: 162–170. https://doi.org/10.1016/j.ufug.2017.11.017.

StatSoft. 2013. STATISTICA, an advanced analytics software package, version 12. StatSoft Inc., Tulsa, Okla, USA. URL: www.statsoft.com.

Wu, J. 2009. Ecological Dynamics in Fragmented Landscapes. In: Simon, L. (Ed.) Princeton University Press, Princeton, NJ, USA, p. 438–444.

Van Den Berge, S., Baeten, L., Vanhellemont, M., Ampoorter, E., Proesmans, W., Eeraerts, M., Hermy, M., Smagghe, G., Vermeulen, I. and Verheyen, K. 2018. Species Diversity, Pollinator Resource Value and Edibility Potential of Woody Networks in the Countryside in Northern Belgium. *Agriculture, Ecosystems and Environment* 259(1): 119–126. https://doi.org/10.1016/j.agee.2018.03.008.