Five military training areas – five different trajectories of land cover development? Case studies from the Czech Republic

Hana SKOKANOVÁ, Marek HAVLÍČEK, Petr KLUSÁČEK,
Stanislav MARTINÁT

***Abstract**: The paper focuses on land cover development in five military training areas (MTAs) in the Czech Republic during the past 180 years and tries to find answers to causes of similarities or differences of this development. Land cover development was researched on the basis of old military topographic maps and aerial photographs. The results show that there are two groups of MTAs that show similarities in land cover development up to the 1960s. These are Březina and Brdy, and Hradiště and Libavá. In the first group, woody vegetation dominated while in the second group open landscape was prevalent. Also the first group was characterized by little population and establishment of military camps already in the 1920s-1930s while the second group was characterized by rather dense population and similar environmental conditions. All MTAs experienced drop of population after WWII which resulted in drop of built-up area and open landscape and increase in woody vegetation area. With the optimisation of MTAs the parts where intensive military training occurs will likely stay preserved while the rest of the areas will be used for ecological agriculture or so called soft tourism.*

***Keywords**: military training area, land cover development, Czech Republic*

Introduction

In present landscapes there are three types of regions where public movement is somewhat restricted. The first type is represented by protected areas (PA) which can be somewhat accessible via tourist paths. The second type is represented by military training areas (MTA) where only army can move freely and the movement of public is forbidden. And the third type is represented by active mining areas (AMA) where only authorized staff can move. In all cases the free public movement wasn't always restricted. The restriction came with declaration of either PA of MTA which usually occurred during the second half of the 20th century and with opening a mine (in the sense of large mining area) which occurred already at the end of 19th century. Before that the land was easily accessible and normally managed.

Another feature common for PAs and MTAs is the fact that they host high biodiversity. In case of PAs it stems from their foundation – they were declared because they represent a diversity hotspot. However, in case of MTAs, this fact is somewhat a secondary outcome of the forbidden free movement and therefore lack of intensive land management. Thus, still active military training areas provides various types of biotopes (Cizek et al. 2013, Wang et al. 2014, Warren and Buettner 2008). AMAs which are abandoned can also develop to biodiversity hotspots (Prach et al. 2014).

While there is quite a lot of literature dealing with land use/land cover changes in protected areas (e.g., Fraser et al. 2009, Jačková et al. 2011, Neubert et al. 2008, Ricca and Guagliardi 2015, Scharsich et al. 2017) or mining areas (Pei et al. 2017, Redondo-Vega et al. 2017, Skaloš and Kašparová 2012, Suto et al. 2017), land use/land cover changes in MTAs are studied sporadically (Gibbes et al. 2017, Olsen et al. 2007, Raska and Kirchner 2011). It is quite surprising since the land use change processes inside MTAs are often very

different from general trends in surrounding landscapes, as described by e.g., van Vliet et al. (2015) or Skokanová et al. (2016), because they are not driven by common economic forces but rather by the specific needs of military. Also, these regions often suffer from depopulation, higher unemployment rates, lack of jobs, insufficient public facilities, inadequate educational structure or transport infrastructure.

Our article focuses on the long term development of land cover in five MTAs that are situated in the Czech Republic and tries to answer the following research questions: has land cover developed differently in each MTA? If so, are the differences statistically significant? And what might be causes of these differences?

Study areas

Five studied MTAs are situated across the whole Czech Republic (*Fig. 1*). Two of them are situated in the border regions – Hradiště near Karlovy Vary in the west and Boletice near České Budějovice in the south. Three MTAs can be found inland – Brdy between Plzeň and Praha, Březina between Brno and Olomouc and Libavá between Olomouc and Ostrava. They were established in their full range after WWII and their borders were delineated between 1948 and 1953. However, two MTAs were established in smaller extent earlier. This concerns MTA Březina which is a successor of Dědice military camp, established in 1936, and MTA Brdy – a successor of artillery shooting range established in 1926.

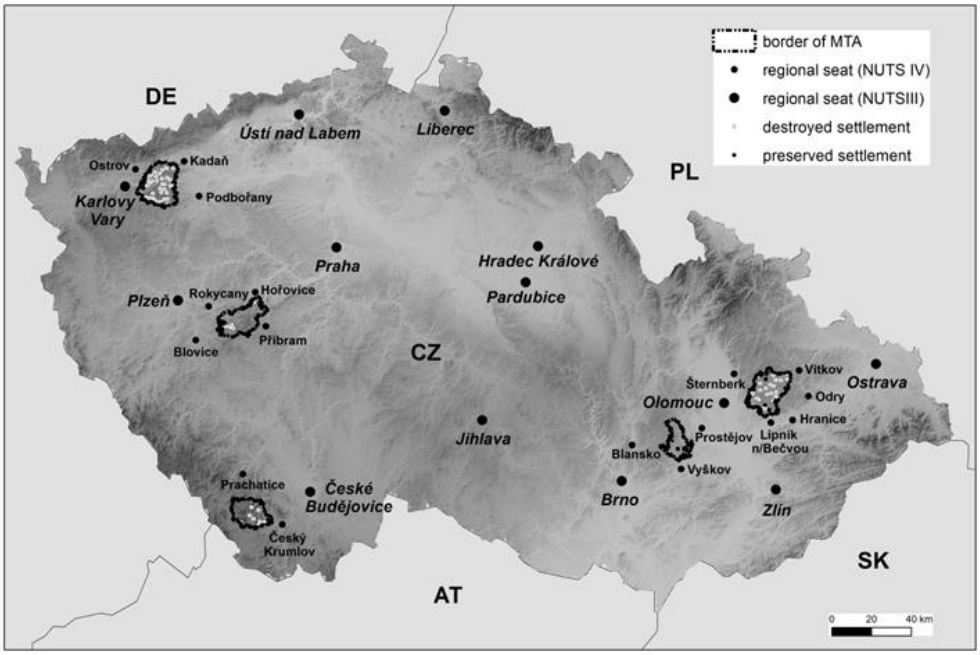

Fig. 1. *Location of studied military training areas (MTAs)*

MTAs are used for different military activities which are summed in *Tab. 1*. In 2016 all MTAs underwent optimization resulting in reduction of their size. This reduction ranged between 5 and 28%. Six new municipalities emerged, three from the released area of the Libavá MTA, two from the Hradiště MTA and one from the Boletice MTA. The military purpose of the Brdy MTA ceased to exist and it was transformed into protected landscape area (only a part of the area has been preserved for military purposes). Area of MTAs before optimization ranged from 158 km^2 to 332 km^2 (*Tab. 1*). This area was also used for analyses of land cover development. Summary of environmental characteristics of the MTAs is stated in *Tab. 2*.

Tab. 1. *Basic characteristics of MTAs*

MTA	date of borders delineation	area before optimization [km^2]	area after optimization [km^2]	military purpose
Boletice	1948	219,50	165,47	all-military training
Brdy	1952	260,09	5,60	artillery, aerial shooting range
Březina	1953	158,18	149,62	preparation and training of specialists
Hradiště	1953	331,58	280,81	all-military training
Libavá	1947	327,24	235,67	all-military training

Tab. 2. *Environmental characteristics of the military training areas (MTA)*

MTA	aver. elev. [m ASL]	min. elev. [m ASL]	max. elev. [m ASL]	main river	aver. annual temp. [°C]	aver. annual precip. [mm]	main soil type	main pot. veget.
Boletice	862	540	1233	Olšina Blanice	3-6	600-1200	C, P	HRBF, ABSF, WSPF
Brdy	639	405	865	Klabavá Litavka	5-8	600-800	C, PG	ABSF, WSPF
Březina	447	260	661	Haná Hloučela	7-8	550-650	C	WSFF, OHBF
Hradiště	592	334	933	Liboc Ohře	5-7	550-800	C	HRBF, OHBF
Libavá	551	270	722	Odra Olešnice	6-7	700-800	C	HRBF

Sources: elevation – DMR model, temperature and precipitation – Tolasz (2007), soil types – soil map of the Czech Republic 1:250 000, potential vegetation – Neuhäuslová et al. (2001). Explanation of abbreviations: elev. – elevation; temp. – temperature; pecip. – precipitation; soil types: C – cambisol, P – podzol, PG – pseudogley; potential vegetation: HRBF – herb-rich beech forest, ABSF – acidophilous beech and silver fir forest, WSFF – woodrush- and silver fir forest, OHBF – oak-hornbeam forest, WSPF – water-logged spruce forest;

It is clear that the MTAs were established in midland to mountain regions. The Březina, Libavá and Hradiště MTAs can be considered as midland regions (elevations 400-599 m ASL), whereas the Brdy MTA belongs to upland regions (elevations 600-800 m ASL) and Boletice represents a mountain region (elevation above 800 m ASL). As such they are usually spring areas to rivers. Thanks to the military regime the MTAs have not been affected by intensive agriculture and therefore represent biodiversity hotspots. This has been recognized by declaring their large parts as NATURA 2000 sites. The only exception is the Březina MTA where no protected areas are present. Only the Libavá and Hradiště MTAs have similar environmental conditions which are shown in *Fig. 2*. This figure shows only those environmental characteristics that represent the landscape of the MTAs the best.

With the exception of the Březina MTA, all MTAs were quite populated before the establishment of the military regime (*Fig. 3*). The largest population was in the Hradiště and in the Libavá MTAs which corresponds with high number of settlements. In the Březina MTA, there were no permanent inhabitants until 1961 and only one settlement existed there. The peak of population in the remaining MTAs was at the end of the 19th century. The population number slightly decreased after WWI, but the strongest decline was recorded after WWII. It was caused by expulsion of predominantly German population by the Beneš decrees. Such high

decline also played a role in the government's decision to establish MTAs in those particular regions. Active utilisation of the MTAs for military activities led to further depopulation and destruction of majority of present settlements. Remaining population consisted mainly of military or people directly connected with military and MTAs (e.g., employees of Military Forests and Farms authority that manages land not used for training purposes).

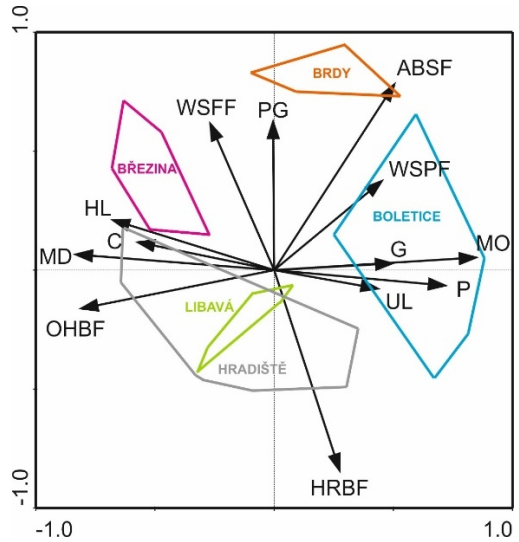

***Fig. 2**. Principal component analysis (PCA) for selected environmental conditions in military training areas (MTAs); HL – hilly lands (200-399 m ASL), MD – midlands (400-599 m ASL), UL – uplands (600-799 m ASL), MO – mountains (800-1399 m ASL), C – cambisol, P – podzol, G – gley, PG – pseudogley, ABSF – acidophilous beech and silver fir forest, HRBF – herb-rich beech forest, OHBF – oak-hornbeam forest, WSFF – woodrush and silver fir forest, WSPF – water-logged spruce forest*

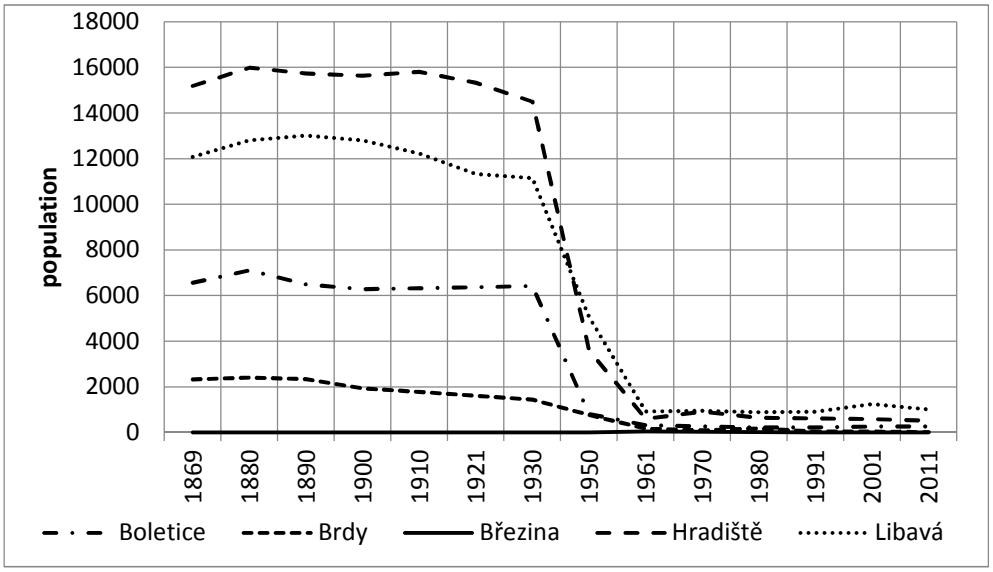

***Fig. 3.** Development of number of population in the military training areas; Source: Balcar et al. (2006)*

Materials and methods

To capture land cover development in MTAs, we used six sets of old topographic maps and aerial photographs. They capture landscape in the second half of the 19th century, at the end of the 19th century, first half of the 20th century, second half of the 20th century, end of the 20th century and present situation. Specifics of the data sources are in *Tab. 3*.

Tab. 3. *Information about source data used for land cover analysis*

period abbreviation	source	scale	period captured
1840s	2nd Austrian Military Survey	1:28 800	1836-1846
1870s	3rd Austrian Military Survey	1:25 000	1876-1879
1940s	revised Austrian Military Survey	1:25 000	1922-1938
	Messtischblatten	1:25 000	1944
	Provisional Czechoslovak Military Survey	1:20 000	1928-1930
	Definitive Czechoslovak Military Survey	1:20 000	1948
1960s	Czechoslovak military topographic maps	1:10 000	1955-1966
1990s	Czechoslovak military topographic maps	1:25 000	1988-1995
2010s	ortophoto	1:5000	2014

The period of the 1940s had to be compiled from multiple sources since none of the above mentioned covered the whole territory of the Czech Republic (Mackovcin and Jurek 2015, Skokanová and Havlíček 2010).

The sources were digitized on-screen and eight land cover categories were distinguished: arable land, permanent grassland, orchards, woody vegetation, water areas, built-up areas and other areas (including mines, ruins and impact areas). These land cover categories are unambiguously identified based on source data (cf. Skokanová and Eremiášová 2012; the name of the category forest was replaced by the name woody vegetation since it better depicts the character of this category – it includes not only forested land but also shrubs and trees outside of forests). Minimum mapped unit was set to be 0.8 ha due to the extent of the researched areas and scale of the sources. Land cover maps in the vector form enabled quantifying changes in the area of individual land cover categories as well as comparison of landscape development between MTAs.

Principal component analysis (PCA) based on square rooted data showed if there were any differences in the land cover among the MTAs. Using ANOVA statistics revealed if there were any significant changes in the development of land cover categories. If that was the case we used Tukey's post hoc test to reveal in which MTAs the significant changes occurred. We also tested if there were any correlations between land cover categories and population. Analyses were carried out using Statistica software, version 10.0 (Statsoft 2004) and Canoco for Windows 4.5 (Lepš and Šmilauer 2003, ter Braak and Šmilauer 2002).

Results

Due to very small proportions of water areas and orchards as well as their rather insignificant changes, these two categories will not be discussed in the further text.

Comparison of the development of land cover in the MTAs showed different behaviour in the PCA (*Fig. 4*). The Brdy MTA and the Březina MTA overlapped in nearly all time periods (with the exception of the 1940s) and the same can be said for the Hradiště and Libavá MTAs in the first three periods.

Both Brdy and Březina MTAs in the 1840s and the 1870s showed high proportion of forests and low proportion of arable land, permanent grassland and built-up area. On the other hand, the rest of MTAs had quite significant proportions of open landscape (in the form of arable land and permanent grassland) and less forest (*Fig. 5*) during the first two periods.

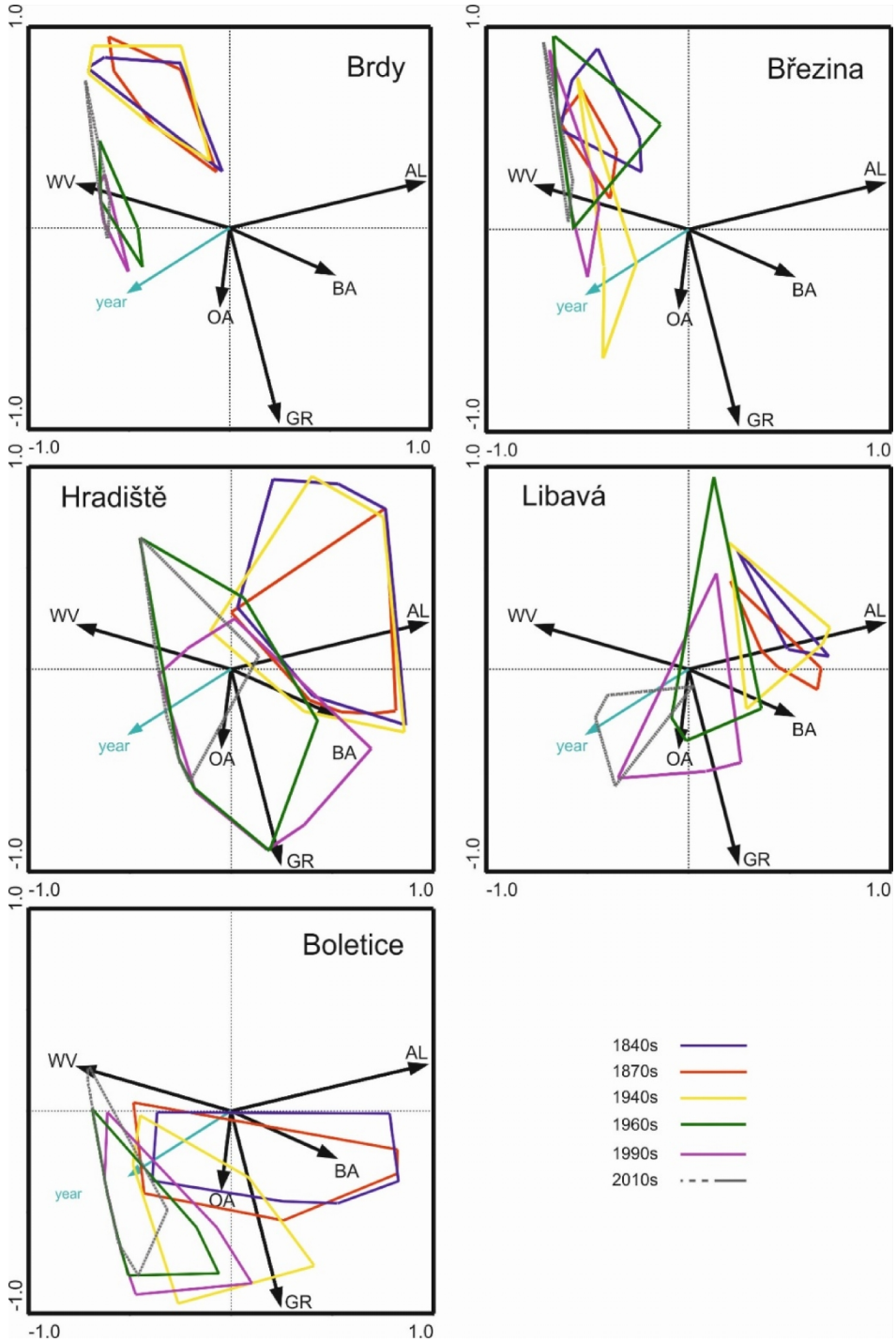

Fig. 4. *Principal component analysis (PCA) based on land cover areas per cadastre, showing shift among the military training areas (MTAs) within time periods; The trends of land cover categories are shown by arrows. AL – arable land, GR – permanent grassland, WV – woody vegetation, BA – built-up area, OA – other area.*

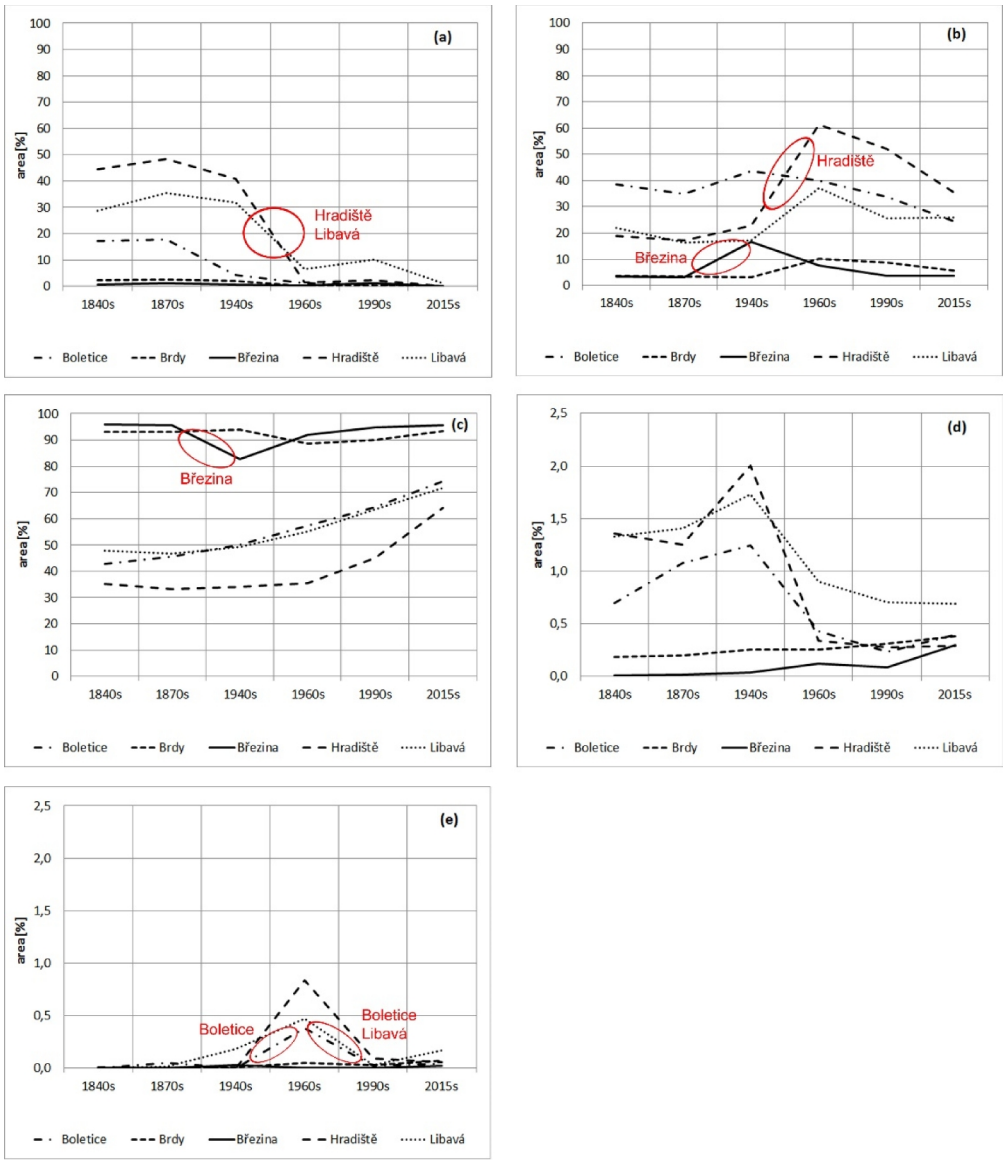

Fig. 5. *Development of selected land cover categories in military training areas (MTAs) in the period 1840s-2010s; a) arable land, b) permanent grassland, c) woody vegetation, d) built-up area, e) other area. Significant differences between periods are marked by red circle and the name of MTA where they occurred.*

In the period of the 1940s the Březina MTA showed significant decline of woody vegetation (also confirmed by Tukey test). This was caused by cutting large proportion of woody vegetation due to the establishment of Dědice military camp in 1936. Transformation of this part of woody vegetation into grassed area lead to similar proportions of this category in the Březina and the Libavá MTAs (*Fig. 5b*). Smaller increases in permanent grassland were also noted for Brdy, Hradiště and Boletice. These MTAs together with Libavá experienced beginning of the decline in arable land. Increase in the built-up area and woody vegetation during the 1940s was typical for Boletice, Hradiště and Libavá.

Period of the 1960s shows clear consequences of the population expulsion and introducing military regime to the regions. It is illustrated by big drop of arable land (*Fig. 5a*), significant decrease of built-up areas that were abandoned and turned to ruins/other areas especially in Hradiště and Libavá, and extensive grassing, significant particularly in Hradiště. Proportion of woody vegetation started to rise in all MTAs with the exception of Brdy where it remained more or less the same (*Fig. 5c*).

Intensive military training after the 1960s was restricted only to training areas. The rest of MTAs was therefore abandoned. This resulted in increase of woody vegetation that took over previous open landscape which is illustrated by decline of permanent grassland and almost non-existent arable land. The only exceptions where arable land was still present in a greater extent were the Libavá MTA and to some extent also the Hradiště MTA. Other area in the form of ruins nearly disappeared. Its decline was significant in the Boletice and Libavá MTAs.

Processes that were initiated in the 1960s and continued during the 1990s continue to the present. Woody vegetation has increased at the detriment of permanent grassland and arable land, which is nearly non-existing. Increase in the woody vegetation between the 1990s and 2010s was the largest of all compared periods. The only exception is the Březina MTA where the biggest increase in woody vegetation cover occurred between the 1940s and the 1960s when the part cleared by Germans during WWII was reforested.

Assessment of relationships between population changes and land cover changes showed that population changes affected to some extent all land cover classes with the exception of other area (*Tab. 4*). Population changes positively affected changes in arable land in all MTAs but Březina. With the increase of the number of inhabitants the area of arable land increased. Population changes had also positive effect on permanent grassland (Boletice) and built-up area in the MTAs with higher number of settlements. Significant negative correlations were found between woody vegetation and population in the Boletice, Brdy and Libavá MTAs.

Tab. 4. *Correlation between population and land cover changes in the military training areas (MTA). Significant differences are marked in bold.*

	Boletice	Brdy	Březina	Hradiště	Libavá
arable land	**0.54**	**0.95**	0.11	**0.34**	**0.85**
permanent grassland	**0.49**	0.03	0.02	-0.15	-0.21
woody vegetation	**-0.63**	**-0.38**	-0.04	-0.19	**-0.63**
built-up area	**0.71**	0.22	**0.37**	-0.03	**0.71**
other area	-0.20	-0.25	-0.07	-0.12	-0.26

Discussion and conclusions

Our results showed that there were indeed differences in land cover development among the MTAs, mainly in the area of arable land and permanent grassland, but also in the area of woody vegetation and the other area (*Fig. 4* and *5*). Statistically significant changes in land cover were associated predominantly with the establishment of training camps before WWII as was the case of the Březina MTA and larger training areas after WWII (the Boletice, Hradiště and Libavá MTAs).

The results revealed similar trends in land cover development for the Březina and Brdy throughout the study period and for the Hradiště and Libavá till the 1960s. The Březina and Brdy MTAs were characterized by high proportion of woody vegetation throughout the whole study period and low number of population. In comparison, the Hradiště and Libavá MTAs were characterized by high proportion of open landscape (arable land and permanent grassland) as well as high number of inabitants. Moreover these two MTAs had similar environmental conditions. The Boletice MTA also had high proportion of open landscape but

it consisted mainly of permanent grassland. The number of inhabitants in this MTA was lower than in Hradiště and Libavá and also the environmental conditions differed from these two (*Fig. 2, Tab. 2*).

During the 19th century, land cover development in the MTAs with larger proportion of open landscape reflected general trends in agricultural intensification at the end of the 19th century that were typical for many European regions (Hersperger and Bürgi 2009, Munteanu et al. 2014). This intensification was predominantly enabled by several factors be it implementation of land reforms (Skokanová et al. 2016), introduction of new crops and management systems (Munteanu et al. 2014) or general population growth. Agricultural intensification during this time was usually accompanied by afforestation of less accessible areas typical for remote mountain regions or peripheral areas of Europe (Agnoletti 2007, Munteanu et al. 2014) where we can also include the MTAs. Yet in the MTAs woody vegetation cover remained more or less the same during this period while arable land increased. This fact might be explained by rather high population in the majority of MTAs with demands on arable land as was confirmed by positive correlation between this land cover category and population (*Tab. 4*). Similar trends occurred also in Polish Carpathians (Bucata-Hrabia 2017) or in Czech Carpathians (Súľovský et al. 2017). More or less the same proportion of woody vegetation during the 19th century could also be explained by increased demand for wood due to glass manufactures (especially in Boletice) and mining (especially in Hradiště and Libavá).

The first half of the 20th century was characterized by slight decrease in the population as a result of WWI and establishment of the Czechoslovakia. Many inhabitants that were predominantly German did not agree with the establishment of the Czechoslovakia and therefore moved from their villages to Germany or Austria. People also moved to larger towns and cities outside of MTAs where it was easier to get jobs in the growing industry. This was true especially for the Hradiště MTA (Matějů et al. 2016). Impact of this fact was reflected in the beginning of decrease in arable land and increase of permanent grassland and woody vegetation, which can be considered as first marks of landscape abandonment (Hersperger and Bürgi 2009). Still, the built-up area increased during this period, mainly due to expansion of some industries (further expansion of glass manufacture, paper industry, or mining industry) in larger towns in the MTAs.

The establishment of the MTAs in the 1950s had significant impact on the landscape in the second half of the 20th century and the trends in land cover development started to be similar in all MTAs. German population was expelled resulting in the dramatic decline of built-up areas that were abandoned and used as targets for artillery training, turning them into ruins. Arable land was systematically transformed to permanent grassland and later either overgrown by successional vegetation or afforested, resulting in the increase of woody vegetation cover. Similar trends have also been recorded in the Slovakian MTA Zahorie (Kušíková 2014), US former MTA Big Oaks (Gibbes et al. 2017) or Czech former MTA Prameny (Raska and Kirchner 2011). Open landscapes remained only around shooting ranges and in places with the most intensive military activities that created new habitats for many endangered species (Cizek et al. 2013, Reif et al. 2011). Parts of the MTAs that were not used for military activities started to be intentionally managed by the Military Forests and Farms authority. This resulted among others in changes of the forest structure – some parts of woody vegetation that spread due to natural succession have been intentionally cut down and replanted usually by spruce. However, majority of successional woody vegetation retained its original species structure.

The last two decades experienced a slight decrease in military activities, resulting in further increase of woody vegetation in all MTAs. Woody vegetation is predominantly represented by forests which have been influenced by forest plans that were largely introduced during the

industrial revolution in the 19th century. These forest plans were primarily focused on wood production resulting in planting namely spruces and more or less ignoring ecological forest functions (Spiecker et al. 2004). Many of such planted forests were and still are strongly affected by drought and pests (e.g., bark beetle). This led to intensive logging resulting to increased environmental risks, e.g., smaller ability to sustain torrential rains or increased erosion of forest soils. Therefore new forms of forest management have started to be supported that focus not only on wood production but also other non-production functions. The new forms of forest management among others accent higher proportion of autochthonous trees, higher deadwood diversity and irregular spatial diversity (Vrška et al. 2017). In the open areas that were not used for military activities, predominantly at the borders of MTAs, organic farming was introduced, resulting in grassing the remnants of arable land. This was true especially for the Libavá MTA.

Optimisation of MTAs that occurred in 2016 resulted in reduction of their sizes and in case of the Brdy MTA in its transformation into a protected landscape area. The size reduction ultimately led to increase of military activities in the remaining parts of MTAs which consequently restricted landscape management of the Military Forests and Farms authority responsible for landscape in the MTAs. Increased military activities might have negative effects on the environment; however there might be some approaches that could mitigate them as was suggested by e.g., Zentelis et al. (2017).

Since the newly released parts of the MTAs have never experienced intensification of agriculture, common for other parts of the Czech Republic, they host many endangered species (Skalicky et al. 2011, Vojta and Drhovska 2012, Bušek and Reif 2017). Furthermore their former inaccessibility might attract not only former residents that were expelled but also general population curious about so called forbidden territory. Both facts might contribute to the development of tourism and recreation in these regions. In such case, there should be plans to balance potential incomes from tourism and preserved natural heritage. One option that is also preferred by Nature conservation authority of the newly established Brdy protected landscape area (PLA), is to forbid construction of recreational facilities in the PLA and situate these facilities in the settlements along the borders while designing tourist and cycling paths inside the PLA.

Another option for using parts of newly set aside territories can be establishment of deer, European bisons, aurochs or wild horses reservations which happened in former military areas of Ralsko (Skalos and Engstová 2010) and Milovice–Mladá. Creation of a deer reservation is probably more feasible since it provides some income from hunting rights and can be created in forested areas that dominate in all new territories. Creation of reservations for European bisons, aurochs and wild horses might be more problematic – these animals need mainly open landscape that is scarce and already used for cattle breeding.

To conclude, up to the establishment of the MTAs in the 1950s there were indeed differences between land cover which were most likely caused by population density and environmental conditions. From the 1950s onwards, the land cover development started to converge in all MTAs, with the process of landscape abandonment manifested mainly by spread of woody vegetation being the strongest one.

From the future perspective it is quite unlikely that the reduced MTAs will experience larger increase in woody vegetation because of their intensive usage by military which needs open landscape for shooting and other training. As for the parts that were taken from the MTAs, due to the character of the landscape and marginality connected with higher unemployment rate we expect that the present landscape management based on implementation of agri-environmental schemes and organic farming will continue to some extent and that some forms of tourism and recreation might occur as well.

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Authors´ addresses:

Hana Skokanová
Silva Tarouca Research Institute,
Lidická 25/27, 602 00 Brno,
Czech Republic
hanka@skokan.net

Marek Havlíček
Silva Tarouca Research Institute,
Lidická 25/27, 602 00 Brno,
Czech Republic
marek.havlicek@vukoz.cz

Petr Klusáček
Institute of Geonics,
Drobného 28, 602 00 Brno,
Czech Republic
klusacek@geonika.cz

Stanislav Martinát
Institute of Geonics,
Drobného 28, 602 00 Brno,
Czech Republic
martinat@geonika.cz