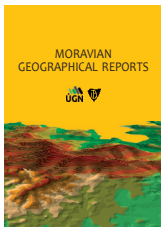

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Tracing the fate of hay meadows with haylofts in Slovakia: A geographical perspective

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Abstract

The paper focuses on the historical distribution of haylofts in Slovakia, geographical conditions related to hay meadows with haylofts, and land cover changes of former hayloft localities. Moreover, the current state of preserved haylofts and the land use of their surrounding area were documented at a regional scale, during the field research. A map of the historical occurrence of haylofts was digitised based on the Czechoslovakian military topographic maps from 1952–1957 (1:25,000). Altogether, 9,742 haylofts were recorded. The haylofts were usually built in mountain and sub-mountain areas on places with low soil quality, mostly at higher elevations, on moderate or moderately steep slopes and in more distant and isolated areas. About half of former hayloft meadows now exist as meadows or pastures with different intensity of grassland management. Forest or shrubs already cover the other 38% of the sites. To a lesser extent, the areas have been converted into arable land or recreational areas. Only a few haylofts have survived to this day; for example, in Upper Liptov Region, it is only 1% of their former abundance in this area (48 haylofts). Apart from a few positive cases where they have been restored or preserved, those that have survived continue to decay.

Key words: *Land abandonment, land cover, grasslands, agricultural history, traditional management*

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1. Introduction

Hay meadows are an important cultural, ecological, and agricultural feature of the landscape, which has been seriously threatened by changes in agricultural practices over the last century (Riley, 2006). Historically, hay meadows were managed with low intensity, that means farming before the spread of modern farming methods connected to chemical fertilisation, drainage, reseeding, and mechanisation often involving a combination of haymaking and pasturing (Janišová et al., 2023) and were characterised by highly diverse vegetation (Sullivan et al., 2018). Several studies around Europe indicated the threats of traditional hay meadows abandonment connected to loss of biological diversity (Norderhaug et al., 2000; Myklestad & Sætersdal, 2003; Marini et al., 2007; Csergő et al., 2013) and cultural heritage associated with hay-making structures (Kruse et al., 2023). Despite its significant decrease since the mid-twentieth century, the fragments of hay meadows can still be found in the landscape. Together with traditional hay making structures, e.g. haylofts and hay sheds, hayloft meadows represent a cultural legacy of traditional landscape management and contribute to biodiversity preservation (Špulerová et al., 2019; Kruse et al., 2023).

In Slovakia, several regions with preserved traditional grassland management were recently documented; however, these systems are preserved without original haymaking storage in haylofts (Janišová et al., 2021) and the haylofts themselves can be found only sporadically. Despite the frequent abundance of haylofts in mountain and sub-mountain areas in the past, there is no comprehensive study on their overall distribution and geographical conditions of their development, nor is the knowledge about the current state of their preservation. The aim of the paper is to fill the gap in this area with focus on the following: 1) historical distribution of haylofts in Slovakia; 2) geographical conditions related to hayloft distribution; 3) changes in land cover of former hayloft meadows; and 4) current state of preserved haylofts and the land use of their surrounding area, and thus to contribute to their knowledge in context of promoting and protecting this biocultural heritage.

2. Theoretical background

Majority of grasslands in Central Europe were developed by human activity, which replaced original forests and open woodland vegetation (Hejcman et al., 2013). Several traditional agricultural systems have been developed in meadow-pastoral landscape, which represent a legacy of traditional management of the European landscape (Burton & Riley, 2018). They include silvopastoral systems, generally referring to ecosystems with sparse trees in open grasslands (Eichhorn et al., 2006; Hartel et al., 2015) that represent one of the oldest land-use types across Europe (Stevenson & Harrison, 1992; Luick, 2008), orchard meadows typical for

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temperate Europe that are connected to different ecosystem services (Forejt & Syrbe, 2019), and to traditional ecological knowledge (Hammel & Arnold, 2012; Žarnovičan et al., 2017; Hutárová et al., 2021; Philipp & Zander, 2023), or hay meadows, that have spread mainly due to the increased cattle breeding and together with significant presence of woody vegetation and typical haylofts, they created the traditional landscape scenery and local colour of mountain and sub-mountain areas (Podolák, 1982).

The European traditional land-use systems have mainly persisted in upland and remote areas where physical constraints have prevented a modernisation of agriculture (Plieninger et al., 2006; Solymosi, 2011; Lieskovský et al., 2014). Previous research has demonstrated the importance of biophysical characteristics such as slope gradient, altitude, or soil quality as drivers of changes when studying traditional landscapes (Rey Benayas et al., 2007; Monteiro et al., 2011; Müller et al., 2013; Druga & Falťan, 2014; Cvitanović et al., 2017).

Hay meadows were preserved in Slovakia until the beginning of agricultural collectivisation, which took place during the communist era (Bezák & Mitchley, 2014; Janišová et al., 2023). The collectivisation process included confiscation of private farmers' property, the establishment of cooperatives and the subsequent land consolidation, and the gradual formation of large-scale agricultural landscapes (Jepsen et al., 2015; Izakovičová et al., 2022). Intensification techniques such as drainage, sowing (after ploughing) or reseeding (without ploughing) of grass and clover cultivars, and intensive fertilisation have completely disrupted the traditional way of farming (Halada et al., 2008), that included clearing the meadows in spring (removing branches and stones), manual mowing once a year, typically in early July, traditional hay-making structures for drying and storage of hay, grazing by livestock in late summer and autumn, and raking in spring and autumn that also provided fertilisation for the meadows (Podolák, 1961). As a consequence of the intensification, there has been a significant impact on the species composition, fostering the development of intensive, species-poor stands (Halada et al., 2008), along with the removal of non-forest woody vegetation and haylofts.

The haylofts are an indelible part of the hay meadow cultural landscape and reflect the former traditional use of mountainous areas (Kušar & Komac, 2019). They are one of the last remaining signs of rural architecture (Palanti et al., 2014). During the winter, haylofts served as storage spaces for hay, which was typically transported to villages using sleighs, usually in the months of January or February. (Podolák, 1962). The system of hay storage was used not only because of the lack of space in the village, but also for safety reasons due to the frequent fires that affected villages with wooden architecture (Podolák, 1982). Construction of haylofts reflected the natural environment in which they were located (Kušar & Komac, 2019). For example, in Italy and Slovenia they were made mainly of wood (Kruse et al., 2023), in France of stone, or wood (Robert, 1942), and comparable stone-built buildings for hay storage exist also in the Pennines in England (Špulerová et al., 2019). In Slovakia, there were only wooden log buildings. They were approximately 4 × 4 metres in size, with roofs covered by shingles (see Fig. 1). Haylofts were without windows and often without doors (Podolák, 1982). The hay was placed in them through a hole in the gable or in the wall of the log cabin. The haylofts were widely distributed in mountain and sub mountain regions of Slovakia and they were built on the lowest mountain meadows, usually on moderate slopes and above the upper edge of the forest (Podolák, 1962).

Although hayloft meadows were widely spread in the Carpathian Mountains and in the Alps (Kruse et al., 2023), the studies targeting haylofts are quite rare. They were devoted to distribution and types of haylofts in France (Robert, 1942), ways of their construction in England (Roberts, 2011), or the classification of the levels of decay in Slovenia (Kušar & Komac, 2019). In Slovakia, ethnographers studied the haylofts only marginally in relation with the local traditional ways of meadows management and hay storage (Podolák, 1961; Podolák, 1962; Podolák, 1982).

3. Methods

The research was carried out at two levels. At the national level, historical distribution of haylofts, evaluation of geographical factors and land cover change was performed. At the regional level, the region with the highest historical occurrence of haylofts was selected to identify the present state and use of preserved haylofts and the land use of the surrounding landscape.

3.1 Study area

Slovakia is located in the Central European region. The georelief is characterised by the mountain arc of the Western Carpathians with a typical alternation of diverse rocks (flysch, crystalline, carbonate and volcanic rocks). The relief culminates in the alpine parts of the High and Low Tatras in northern Slovakia with the highest peak Gerlachovský štít, reaching 2,655 metres a.s.l. The lowlands are located in the south and southeast of Slovakia, with

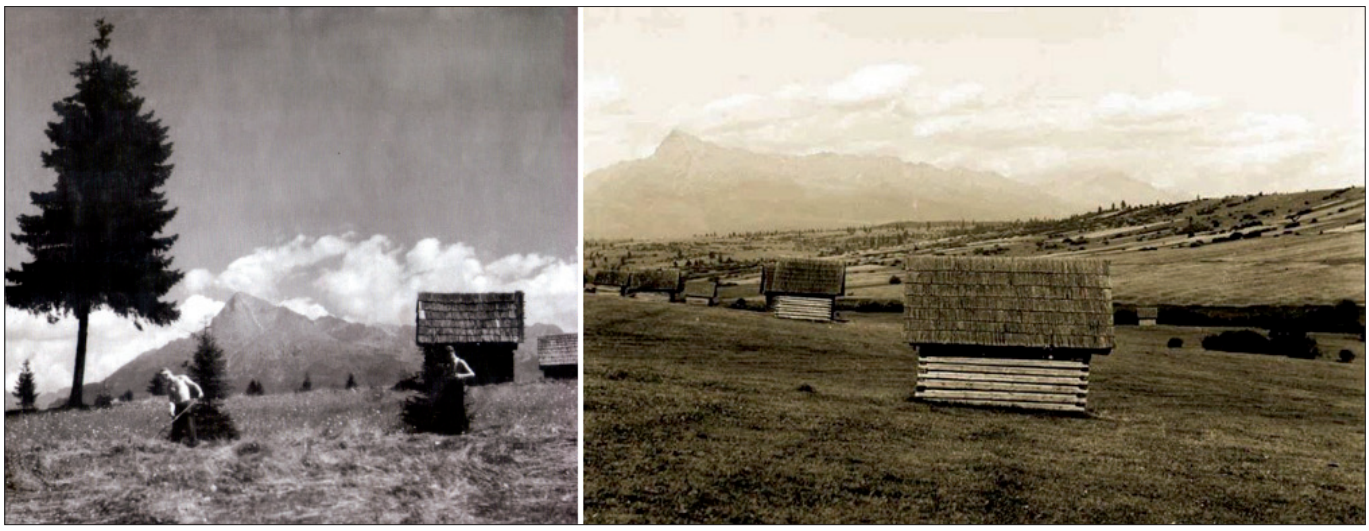

Fig. 1: The haylofts in historical photographs in 1950s: Meadows with solitaires of trees and haylofts (left) and haylofts in the cadastral area of Východná (right)
Source: The archive of Východná municipality (2002)

the lowest point at Dolný Zemplín near the Bodrog River, which reaches 94 metres a.s.l. The population density is 111.2 per km^2, and the total area is 49,034 km^2. According to the Statistical Office of the Slovak Republic (2021), lowlands (up to 300 metres a.s.l.) occupy 41% of the territory, low highlands (301–750 metres a.s.l.) occupy 45% of the territory, and areas over 751 metres up to 2,655 metres occupy 14% of Slovakia. For generations, the Slovak economy has been heavily dependent on agriculture. The lowlands are suitable for cultivating crops such as wheat, barley, corn, or vegetables. The hilly and mountainous regions are more suitable for animal husbandry, such as cattle and sheep breeding.

Regional study was carried out in the Upper Liptov Region, situated in the northern part of Slovakia (Fig. 6), between the Low Tatras Mts. in the south and the High Tatras Mts. in the north. The majority of the region belongs to a moderately cold and very humid climatic area, with soils dominated by pseudogleys, cambisols and rendzinas (Atlas of the Landscape of the Slovak Republic, 2002). The area covers 805 km^2. The area was settled from the 13th century, and was influenced by three colonisation waves – German, Wallachian and partially highlander colonisation (the last two were shepherds). Due to the harsh climatic conditions, the animal husbandry oriented towards sheep and cattle breeding prevailed. Until 1948, the region consisted of 18 municipalities.

3.2 Mapping the historical distribution of hayloft

Identification of the historical distribution of haylofts in Slovakia was based on Czechoslovak topographic military maps (1:25,000) from 1952–1957. The maps were produced by the Military Topographical Institute in Banská Bystrica using a photogrammetric foundation. Online version of the map set is provided by the Ministry of the Environment of the Slovak Republic, freely available at the National Geoportal (https://geoportal.gov.sk/maps/historical-maps/). Maps show the situation before, or at the very beginning of the establishment of cooperative farms linked with agricultural intensification and collectivisation. The identification of hayloft meadows and pastures on the historical maps is documented in Figure 2. Haylofts were digitised to point GIS layer. The data were processed using the ArcMap 10.3 software (ESRI, 2016) that was used for all GIS procedures applied in this study.

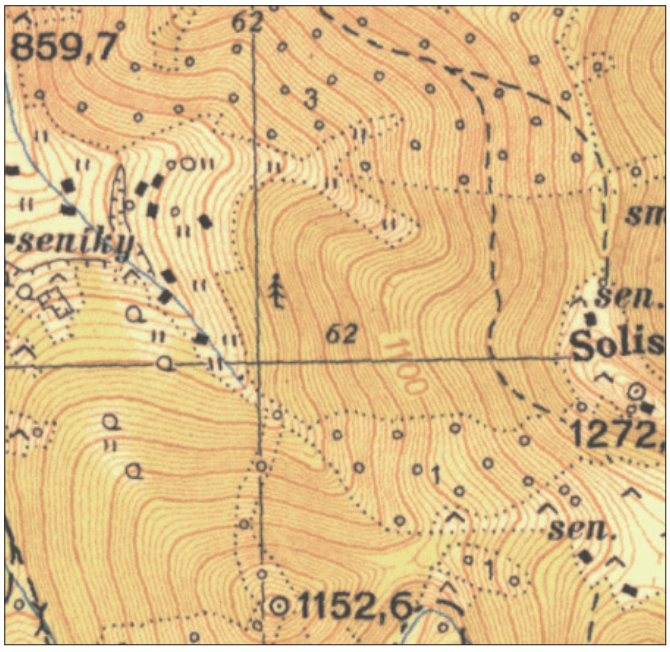

Fig. 2: Military topographic maps from 1950s
Source: National Geoportal
Legend: ■ sen./seníky – hayloft/haylofts, " – meadow, ^ – pasture

3.3 Analyses of geographical factors

We identified the environmental conditions of hayloft meadows based on literature, expert knowledge of the area and the data availability. We performed a correlation analysis (see Appendix 1) and chose the most representative variable from the strongly correlated ones. We chose altitude and slope as basic relief characteristics explaining the haylofts distribution. The topographic data were obtained from a digital elevation model (DEM) with resolution 30 m that was derived from contour maps at the scale of 1:10,000.

Soil fertility was obtained from the national database of soils provided by the National Agricultural and Food Centre in Bratislava. Fertility is expressed as soil production potential derived from soil type, slope steepness, aspect, skeletal content and depth, grain size distribution, and climate factor (Džatko, 2002). The soil production potential is expressed on a relative scale of zero (the least productive soils) to 100 (the most fertile soils).

From the distance factors, we analysed accessibility and isolation. Accessibility was evaluated as walking distance from the nearest settlement in minutes. The analysis included the effect of topography and different land cover types that could slow walking speed (meadows, cropland, forest), could have a barrier effect (buildings, rivers), or could facilitate walking (paved roads, paths, bridges, etc.) (Druga & Minár, 2023; Lieskovský et al., 2017; Rusinko & Druga, 2022). As a source of land-cover data, we used the Corine Land Cover from 1990 (European Environmental Agency & Copernicus Land Monitoring Service, 2019) as the oldest available national-wide land-cover data source, which reflects the closest available source to the years of mapping haylofts. The effect of different land cover classes on walking speed were derived from empirical experiences and from published literature (Soule & Goldman, 1972; Mezníková, 2011; Lieskovský et al., 2014).

Similarly, the isolation was evaluated as the distance by car to the regional centre in minutes. We employed the present-day road network map, excluding newly constructed highways since the time of collectivisation. We did not have the information about average car speed on the roads; therefore, we employed maximum car speeds limits: 120 km.h^{-1} for established highways and 90 km.h^{-1} for roads. Additionally, we incorporated pedestrian distances from roads to the hayloft areas inaccessible by car. The VARCOST module from the IDRISI software was used for the analysis.

Microclimatic variables were represented by solar radiation. Solar radiation expresses the average amount of solar energy received from the sun per year. It was calculated with the Area Solar Radiation tool included in ArcGIS Spatial Analyst toolbox from a digital elevation model with resolution 10 metres. We did not consider classical climate variables as average temperature or rainfall, because they are strongly correlated to the altitude.

To analyse the role of geographical factors related to the haylofts' occurrence, we compared the distribution of haylofts with the historical distribution of grasslands. The information on the historical grassland distribution was taken from the map of historical land cover of the Carpathian region (Lieskovský et al., 2018). The land cover was mapped in a 2 × 2 km point square grid from the Czechoslovak topographic military maps at the scale of 1:25,000 from 1952–1957. Four classes represented the grasslands: wet meadows, dry meadows, wet pastures, dry pastures. For our analyses, we selected dry meadows and dry pastures, because the haylofts were not situated on wetlands. Due to the high spatial autocorrelation of the hayloft data, we were not able to perform a statistical test of significance of the differences.

3.4 Analysis of historical land cover of hayloft localities and changes of land cover (1950s–2018)

We used the same maps for historical land cover of hayloft localities as we did for the identification of haylofts. Meadows and pastures, distinguished on the maps as two categories (Fig. 2), were merged into one category as grasslands for further studying the land cover changes. To identify current land cover, we used the CORINE land cover map (European Environmental Agency & Copernicus Land Monitoring Service, 2019), but some categories were slightly modified (Tab. 1). In order to determine land cover classes accurately, their occurrence was manually compared with aerial photographs from 2018 to minimise the error rate (this mainly concerned small grasslands or their peripheral parts that were included in the forest area under the CLC). We distinguished following land cover categories given in Table 1.

To document the current state and condition of preserved haylofts and the land use in their surrounding area, a field survey was performed in 2022–2023 in the Upper Liptov Region. The area was selected on the basis of the highest number of identified haylofts among the regions of Slovakia (Fig. 1). We identified the occurrence of haylofts based on our previous research knowledge and the aerial photographs from 2020. All identified haylofts were subsequently verified in the field, photo documented, and classified according to modified classification of Kušar and Komac (2019) to three categories: (1) without visible damage; (2) partly, or entirely damaged roof, wall timbers without damage; (3) damaged wall timbers, or just some remnants of logs, or traces visible, but still possible to identify the hayloft´s layout.

4. Results

4.1 Historical distribution of haylofts

In the whole territory of Slovakia, we identified 9,742 haylofts, which were localised in the cadastres of 161 municipalities (5.57% of the total number of municipalities in Slovakia) and 26 districts. Hayloft meadows were unevenly distributed across Slovakia. We identified three main spatial clusters of hayloft distribution (see Fig. 3):

1. Partially the counties of Liptovský Mikuláš and Poprad (historically the Upper Liptov Region) – 4,537 haylofts (46.57% of all identified haylofts);
2. Partially Ružomberok and Martin districts (partially the former Lower Liptov Region and Turiec region), with 1,820 haylofts (18.68% of all identified haylofts);
3. Partly the counties of Banská Bystrica and Zvolen (historically partially Zvolen County) had 1,204 haylofts (12.36% of all identified haylofts).

4.2 Geographical conditions related to haylofts distribution

The haylofts were localised at higher elevations peaking at altitudes of 700–900 m a.s.l. From this point onwards, their number gradually decreased with increasing altitude. The mean altitude of haylofts was 819 m a.s.l. (standard deviation 180 m), which differed significantly from the average value of altitude of grasslands (522 m a.s.l., and standard deviation 320 m). Most of the haylofts were located on moderate or moderately steep slopes, with

Land cover type	Description
Forest	Broadleaf, coniferous and mixed forests
Shrub communities	Succession stages with dominance of shrub communities, riparian shrubs
Water bodies	Water dams and fishponds
Grasslands	Meadows, pastures and natural grasslands above the treeline
Land principally occupied by agriculture	Mosaics of small patches of arable land and grasslands
Arable land	All arable lands except of small patches of arable land in mosaics with grasslands
Discontinuous urban fabric	Residential areas and residential facilities, including individual houses, roads within residential areas, home gardens
Industrial units and roads	Mining areas, industrial units, roads, motorways and motorway rest areas
Sport and leisure facilities	Sports fields, recreational areas, or individual cottages mapped within 30 m radius from the historical occurrence of haylofts

Tab. 1: Identification and classification of preserved haylofts at regional level
Source: Authors' elaboration

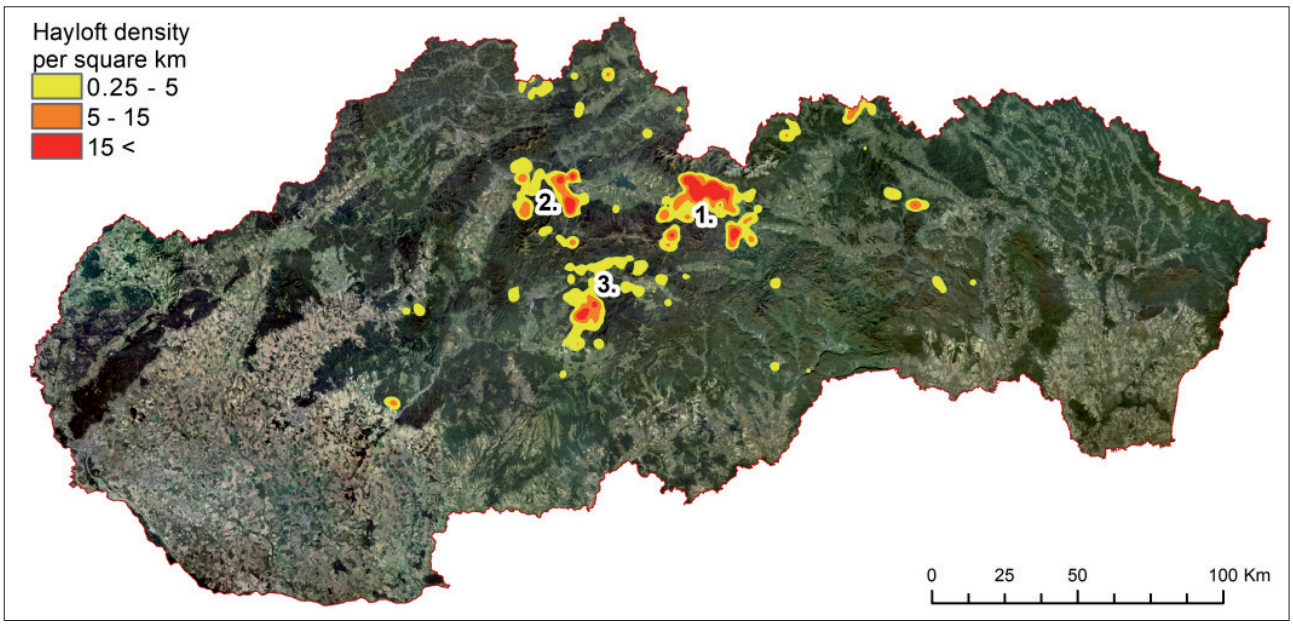

Fig. 3: Hayloft density in 1950s
Source: Authors' elaboration

maximum reaching 37 degrees. Although haylofts were favoured on locations with slightly higher slopes, the average slope values of hayloft localities (10.1 degrees, standard deviation 6.7) and grasslands (9.7 degrees, standard deviation 7.8) were similar.

The haylofts were built in locations with less fertile soils ranging mostly from 20 to 30 of soil quality (on the scale of zero with the least productive soils, to 100 with the most fertile soils), an average value of 25 (standard deviation 11.5), in contrast to grasslands with average soil quality of 37 (standard deviation 21.1). The "distance to village" indicator shows that haylofts were more remote from the nearest villages – 67 min on average (standard deviation 35.3) compared to grasslands (mean distance of 47 min, standard deviation 42.4). The attribute of "distance from regional centres" also documents that areas with haylofts were more isolated. Average distance from regional capital city by car was 62.1 min (standard deviation 29.2) to haylofts and 59.3 min (standard deviation 47.2) to meadows. The differences in median value are even more noticeable (Fig. 4). The haylofts were built in areas with slightly higher solar radiation. Average solar radiation was 1,199,792 Wh.m^{-2} (standard deviation 117,772) for haylofts and 1,181,361 Wh.m^{-2} (standard deviation 100,666) for meadows.

4.3 Changes in land cover of hayloft meadows

In the past, almost all haylofts were located on meadows or pastures, only a few of them were located at the edge of the forest or even on edges of fields (0.5% of all recorded haylofts). More than

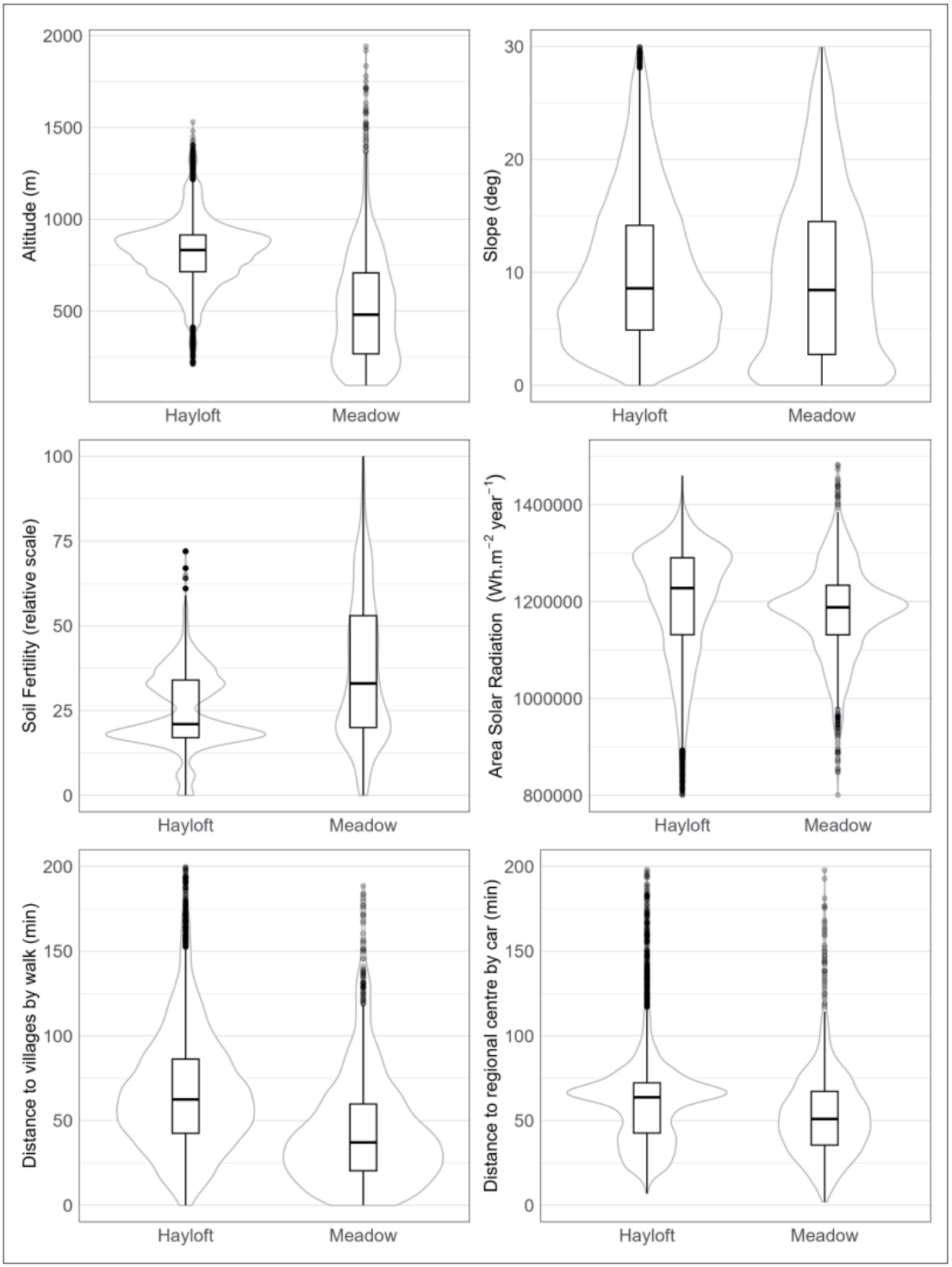

Fig. 4: Diagrams showing the differences in influence of selected factors between the hayloft localities and meadows
Source: Authors' elaboration

half of former hayloft localities (51.17%) were changed during the past 70 years. A large part of the sites is overgrown by forest or is in various stages of succession. Some of the former hayloft meadows have been converted into arable land. Changes related to urbanisation were connected with enlargement of settlements, creation of recreational sites, or to a lesser extent, to water bodies (hydroelectric power plant, water reservoir and ponds), roads, or industrial areas (Fig. 5).

4.4 Current state of preserved haylofts in the Upper Liptov region

During the field survey, the haylofts of Upper Liptov region that have survived to date were recorded (see photos on Fig. 6). Out of 74 wooden features originally identified from recent aerial photographs, 48 were haylofts. The remaining objects were ruins of winter stables (at villages of Vyšná and Nižná Boca), cottages or barns.

Most of the recorded haylofts were roofless, or collapsed, in most cases with shrubs growing inside, or outside the walls. We also identified preserved haylofts, which no longer fulfil their original function of storing the hay, but are used for different purposes, such as buffet for skiers located on the ski slope (one hayloft), recreational cottage without water and electricity (one hayloft), or for storage as sheds (three haylofts). Quite a number of preserved haylofts had a shingle roof covered with metal sheeting, which prolonged their life. Only in five cases, we found haylofts with preserved original shingle roofs (Tab. 2).

The surrounding land was used in 35% as mowed meadows, or pastures for cattle, 13% were recently abandoned (grasslands without non-forest woody vegetation), and in 6% their immediate surroundings were rebuilt. Almost half of the surrounding land undergoes succession, when 38% of sites are abandoned and overgrown by shrubs and 6% of sites are already covered by forest. Several areas of the former hayloft meadows are currently under pressure from the construction of recreational cottages (see Fig. 7).

5. Discussion

5.1 Using the historical topographic maps for mapping the haylofts

We used historical topographic maps from 1952–1957 to identify historical distribution of haylofts on hay meadows in Slovakia, which captured the situation before the collectivisation largely. Altogether, in the 1950s, we identified 9,742 haylofts, localised in the cadastres of 161 municipalities, out of which in 25 cadastres the process of collectivisation started already, as newly established cooperative farms were identified together with haylofts. Therefore, it can be assumed that in these areas there may have been more haylofts, which may have already been removed due to intensification processes during collectivisation (such as land consolidation, removal of non-forest woody vegetation and haylofts, drainage, and reploughing and reseeding of grass species.

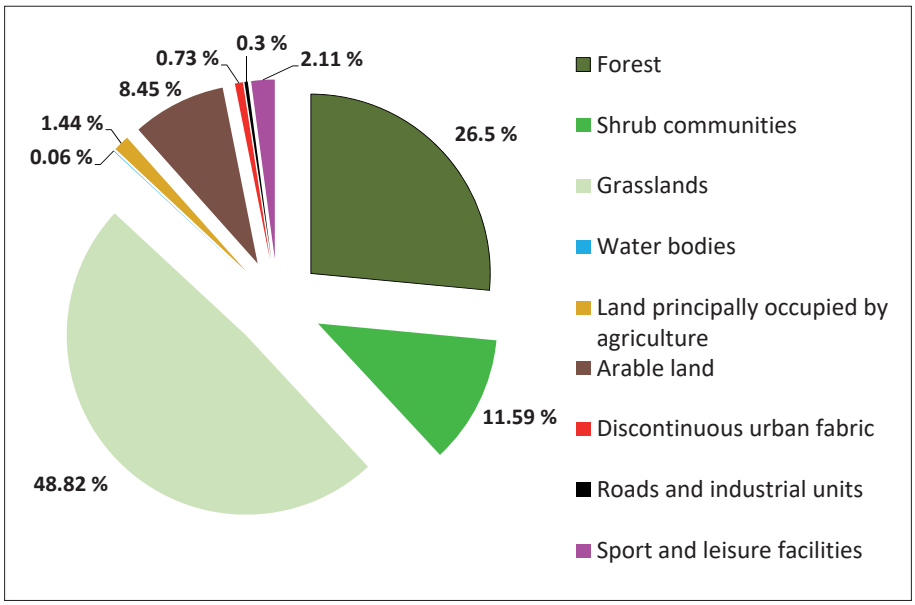

Fig. 5: Current land cover of former hayloft localities
Source: Authors' elaboration

Fig. 6: Example of different stages of decay of haylofts in the Upper Liptov Region – from left to right: (a) Preserved hayloft in a complex of hay meadows with high biodiversity in Liptovská Teplička – type I.; (b) Damaged hayloft in the cadastre of the Nižná Boca – type II.; and (c) Remnants of the hayloft in Nižná Boca – type III
Photos: Z. Baránková (2023)

Haylofts			Surrounding landscape						
Type of preservation	Current use	Condition of haylofts	Meadow	Pasture	Overgoing succession with shrubs	Overgoing succession with shrubs and trees	Urbanisation	Recently without agricultural use, without shrubs and trees	**Total**
I	No	Preserved with original shingle roof	2			1		1	**4**
		Preserved with repaired tin roof	2			1		4	**7**
		Preserved as a cottage					1		**1**
	Yes	Preserved with original shingle roof		1					**1**
		Preserved with repaired tin roof	3						**3**
		Preserved as a cottage	1						**1**
II.	No	Damaged shingle roof		1			1		**2**
III.	No	Shrubs inside, collapsed roof and partially damaged side timbers	1	3	11	1	1	1	**18**
		Shrubs inside, collapsed roof, side timbers preserved	2	1	6				**9**
		Shrubs inside, traces only			1	1			**2**
Total			**11**	**6**	**18**	**4**	**3**	**6**	**48**

Tab. 2: The present state of haylofts and use of surrounding landscape
Source: Authors' elaboration

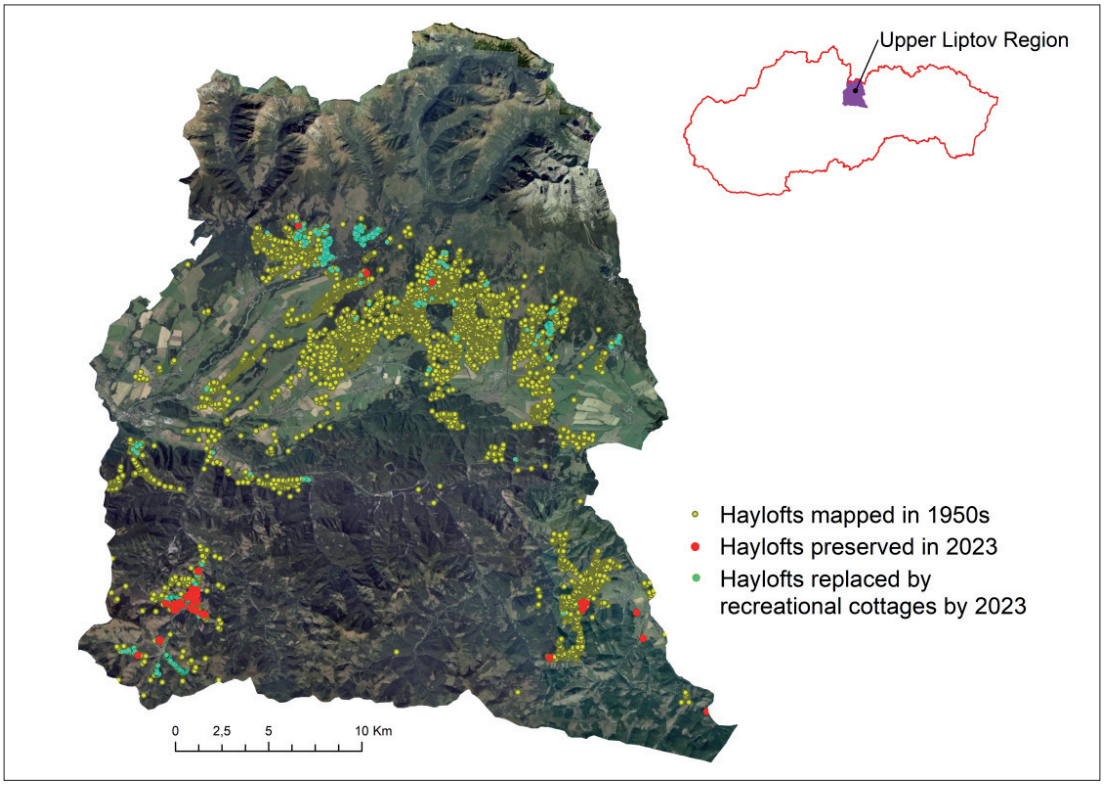

Fig. 7: Distribution of identified haylofts and recreational cottages in the Upper Liptov Region in 2023
Source: Authors' elaboration

Despite this, the topographic maps that were used represent the best historical source for identifying haylofts for the large-scale study in contrast to cadastral maps that can be used for local or regional studies. Moreover, the haylofts on the maps can be easily distinguished from other buildings in the countryside (sheds, outbuildings, but also houses in areas with dispersed settlement) on the base of their clear designation and labelling. As for the other sources on the historical distribution of haylofts, we can use the maps of the first Austrian military mapping (1763–1787), the second Austrian military mapping (1806–1869), both at the scale of 1:28,800 and the third Austrian military mapping (1857–1883) at the scale of 1:25,000 (Timár et al., 2011). According to these maps, the haylofts were already present in the area, but the presence of haylofts was marked schematically and does not give a realistic image of their real numbers.

5.2 Geographical conditions related to haylofts distribution

Altitude is an important geographical factor related to various environmental gradients like temperature, moisture, wind and also human land use (Körner, 2007). Hayloft meadows in Slovakia were predominantly situated in areas at elevations ranging from 700 to 900 metres, because lowlands in Carpathian areas were historically transformed to agricultural fields (Munteanu et al., 2014; Lieskovský et al., 2018) and most of the grasslands remained in submountain and mountain areas. Elevation and slope representing terrain were also the most important variables determining grazing localities in Europe, except in the Mediterranean South (Malek et al., 2024).

Significant role of slope steepness in landscape development was confirmed in various studies from Europe (MacDonald et al., 2000; Giampaolo et al., 2012; Opršal et al., 2013; Bajocco et al., 2016)

and Slovakia (Lieskovský et al., 2015; Masný et al., 2017; Pazúr & Bolliger, 2017). Our study shows that most of the haylofts were located on moderate or moderately steep slopes ranging mostly from 5 degrees (1st quartile) to 14 degrees (3rd quartile), which is in line with other studies (Robert, 1942; Podolák, 1962). However, we found that slope steepness did not play a significant role in hayloft location in comparison to other grasslands.

Distance of haylofts from nearest settlements was higher in comparison to other meadows. The hay meadows (the so-called back meadows) were located in remote areas and hay was stored in haylofts located on those meadows. This was the main difference from the meadows located closer to the village (the so-called front meadows), which were mowed twice a year, and the hay was transported to the barns in the village. By tracking "walking distance", we confirmed and quantified the average distance of these meadows from the villages, and also differentiated them from other meadow types. Higher distances from the nearest settlements are also associated with abandonment of agricultural land (Prishchepov et al., 2013; Fonji & Taff, 2014; Malek & Verburg, 2020). Isolated communities rely more on self-sufficiency (Renes, 2014), which could be also related to hay meadows. In addition, the isolation prevents modernisation and determines persistence of traditional agriculture (Solymosi, 2011), because farmers see traditional systems as a barrier of modernisation through mechanisation (Eichhorn et al., 2006).

Haylofts were built on meadows with lower soil quality compared to other grasslands. In general, the meadows were medium-productive, and their fertility was increased by mowing or fertilising with manure or wood ash. On the lowest quality soils (often in high altitudes), pastures were located. The rich, fertilised meadows mown twice a year were located near villages and more remote, less accessible sites hosted single-cut grasslands and in some regions with location of haylofts (Podolák, 1961). Here the rotation of mowing and grazing (meaning also fertilisation) was applied and formed a transition to the foothill pastures (Halada et al., 2008). The alternating mowing and grazing of hayloft meadows is evident also on the military topographic maps from 1950s, where haylofts are recorded on meadows, but also to a lesser extent on pastures (Fig. 2), or occasionally even on field margins. The combination of mowing and grazing was traditional practice of hay meadows management also in other parts of the Carpathians and this system is today highlighted as a practice supporting grasslands conservation and restoration (Dmytrash-Vatseba & Shumska, 2020; Janišová et al., 2023).

The macroclimatic factors as annual average temperature or precipitation are highly correlated with altitude; therefore, we selected the annual solar radiation for the representation of microclimate parameters. It is the factor with the greatest influence on hay drying (Rotz, 1993). The haylofts were preferably built on areas with higher solar radiation. The hay from hayloft meadows was stored for longer periods, and so there was a need to ensure good quality drying of the hay. This was assured by locating the haylofts in sunny areas.

5.3 Current state of haylofts and land cover changes of hayloft meadows

Central and Eastern Europe has been one of the global hotspots of agricultural land abandonment in recent decades (Kuemmerle et al., 2016; Munteanu et al., 2017; MacDonald et al., 2000). Marginal mountain areas were more prone to abandonment (Kuemmerle et al., 2008; Pazúr et al., 2020), which is in line with our study. Almost 38% of sites have been influenced by abandonment and have changed to forest or shrub communities. The change of permanent grasslands into shrub and forest associations as the most important change of farmland was confirmed also from other Slovak regions (Šebo & Kopecká, 2014; Feranec et al., 2017). On the other hand, 11% of the sites have been modified by intensive human activity (construction of cottages, conversion to arable land, construction of motorway, etc.). The level of abandonment of former hayloft localities can be also indicated according to the stages of hayloft decay. Kušar and Komac (2019) presented a classification of the levels of decay of haylofts, which they used as an innovative indicator of changes in the cultural landscape. By using a simplified version of this classification, we observed almost 65% of the haylofts in different stages of deterioration.

Detailed field research in the Upper Liptov Region shows that only 1% (48 haylofts) of the original haylofts has been preserved and most of them are in different stages of decay. Preserved ones are not used for storing hay anymore. This is in line with the overall decline of traditional farming in Slovakia. Less than 2% of traditional agricultural landscapes survived collectivisation of agriculture (Lieskovský et al., 2014) and half of them are in the different stages of abandonment (Lieskovský et al., 2015). Abandonment of traditional agricultural practices and associated loss of biodiversity, ecological knowledge, biocultural (Agnoletti & Emanueli, 2016; Baránková & Špulerová, 2023) and other values is an ongoing worldwide issue (Tarolli et al., 2014; Varotto et al., 2018; Vasilescu et al., 2023).

In addition to the analysis of the geographical factors under which hay meadows were formed, future research should also be extended to sociological characteristics and historical settlement development, which most likely also played a significant role in the location of hayloft meadows in Slovakia. Another important issue is the high biodiversity value of former hayloft meadows (Ružičková & Kalivoda, 2007) and impact of current environmental schemes, the extent to which they contribute to the conservation of species-rich, semi-natural hay meadows.

6. Conclusions

Former hayloft localities differed mainly in geographical conditions related to altitude and soil fertility compared to other grasslands. More than 50% of the sites are now overgrown with forests or undergoing succession processes. Their rich historical legacy is, to a small extent, still evident today through the preservation of haylofts as witnesses to traditional farming. However, only 1% of them have survived in the study area, from which, most of them have deteriorated. They are no longer used for hay storage, but they are sporadically used as sheds, cottages, or as a shelter for skiers. The haylofts, together with traditional species-rich hay meadows with high biodiversity created the traditional landscape scenery and can be considered as valuable biocultural heritage of Slovakia related to agricultural landscape, which has almost disappeared. The question of preserving the last remnants of hay meadows is therefore very current, and ways to preserve them should be sought, for example within agri-environmental schemes.

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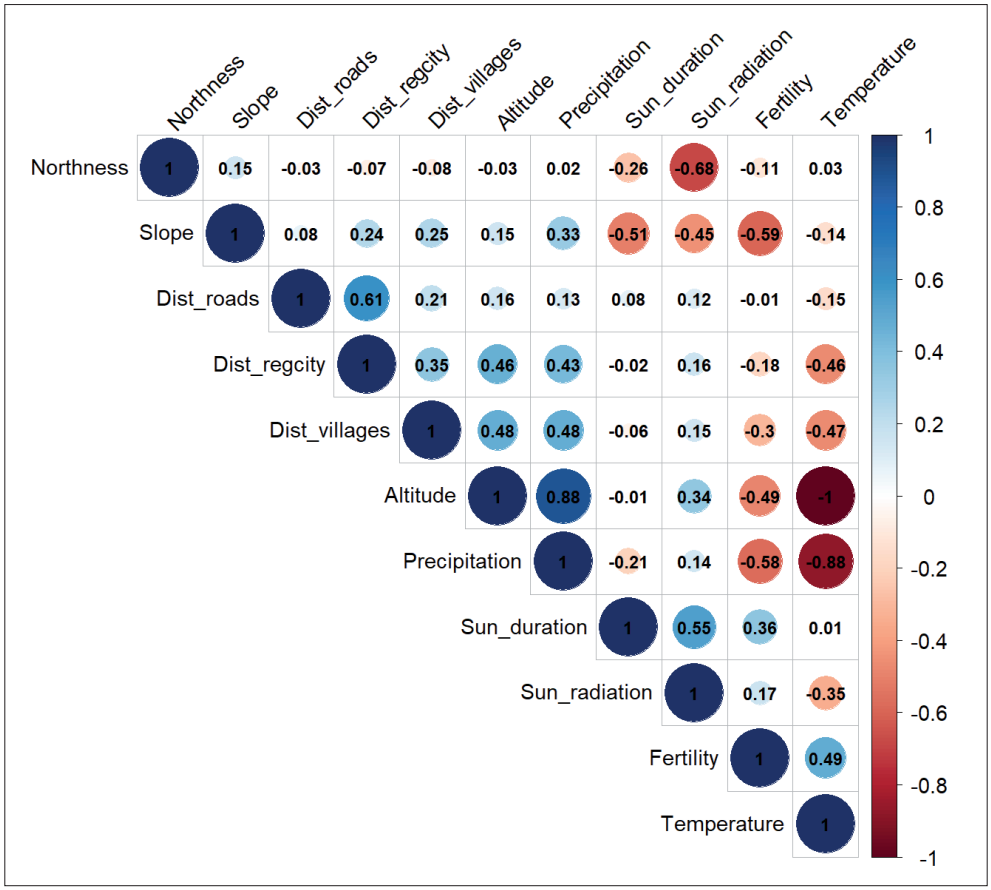
Appendix



Appendix 1: Correlation analyse of selected variables

- *Northeness: Cosine of aspect (in radians)*
- *Slope: Slope steepness (degrees)*
- *Dist_roads: Distance to roads (meters)*
- *Dist_regcity: Distance by car to regional centre in minutes*
- *Dist_villages: Walking distance from nearest settlement in minutes*
- *Altitude: Altitude (meters above sea level)*
- *Precipitation: Monthly means of rainfall (1990–2000)*
- *Sun_duration: Time of sunshine duration (incorporated effect of hill shading) in hours per year*
- *Sun_radiation: Average amount of solar energy received from the sun per year ($Wh.m^{-2}$)*
- *Fertility: Soil production potential derived from soil type, slope steepness, aspect, skeletal content and depth, grain size distribution, and climate factor (relative scale)*
- *Temperature: Monthly means of temperature (1990–2000)*