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# Recent land cover change with regard to heterogenic abiotic conditions in watershed of a high mountain stream in the Western Carpathians, Slovakia

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**Abstract.** In today's rapidly changing world, a focus on nature conservation is still not prevalent enough in research providing us with existential values. In this study, we evaluated the recent change in landscape cover over a selected part of the Javorinka mountain catchment. Using editing of aerial orthophotos from between 2010 and 2019, we developed a detailed landscape cover layer, evaluated by ArcMap software. Within this relatively brief period of nine years, we observed a subtle shift of vegetation zones to higher elevations as well as a significant loss of healthy forest to wind disturbance and bark beetles. Based on our results, the natural regeneration capacity of the forest is evident, where we observe a significant increase in the area of young forest over the area of previously damaged forest and dry or dead forest. At the same time, we observed almost no significant changes in artificial surfaces, indicating a general trend of urbanization and depopulation of rural areas. The contribution of this work lies in the attempt to explain and understand short-term landscape cover changes in a small but heterogeneous mountainous environment, and the resulting effort to better adjust conservation management.

*Key words:* landscape cover, mountain watercourse catchment, GIS, zonal analysis

## Introduction

It is increasingly challenging to understand the importance and complexity of the phenomena taking place in the ecosystems around us. It is in this context that contemporary society is witnessing increasing ecosystem fragmentation, habitat loss and the systematic breakdown of functional ecosystems (Nilsson and Grelsson 1995; Wang *et al.* 2016; Fardila *et al.* 2017). With projections pointing to a gradual increase in temperature and changes in precipitation regimes, it is important to recognize how the landscape around us has already changed to date, influenced by these factors. Using land use/land cover (LULC) tracking, which is a strong representation of ecosystems, we can effectively track these changes between time horizons (Zimmermann *et al.* 2010).

Geographic Information Systems (GIS) have proven to be an effective tool for tracking these changes, largely through satellite and aerial imagery (Alqurashi and Kumar 2013). Over the last 60 years, GIS has developed as a discipline in its own right and its use has grown considerably over this time, so that today we are able to obtain detailed and, above all, comprehensive information about the Earth's surface (Weiss and Walsh 2009). Remote sensing instruments are highly efficient when dealing with larger areas of the Earth's surface, and is why we chose to process both time horizons in this way.

Today, in the European high mountains we are witnessing significant trends of abandonment of human settlements, loss of interest in agricultural activities in mountainous areas and a reduction in the intensity of livestock grazing in mountain areas (Walther 1986; Tasser and Tappeiner 2002; Zimmermann *et al.* 2010; Czortek *et al.* 2018a). These factors are associated with historical socio-economic changes, especially in the Carpathian region and Eastern Europe in general (Kanianska *et al.* 2014; Kijowska-Strugała 2019). These factors are subsequently reflected in natural changes in landscape cover, where former grassland areas are gradually becoming overgrown, and the upper forest limit is increasing at their expense. Interestingly, causes other than climate change have emerged. For example, the overgrowth of former grasslands, with Gehrig-Fasel *et al.* (2007) pointing out that when the upper forest limit shifted in the Swiss Alps, this factor had up to 90% of the total influence versus 10% of the actual climatic shift.

The percentage of shrubs and forests increases. There is also afforestation of abandoned agricultural areas, mostly in areas with steeper slopes, which tend to be the first abandoned (Tasser *et al.* 2007). On the other hand, there is also an increase in human development in the form of tourism infrastructure, which could be expected to develop as a substitute for income from agricultural and pastoral activities (Kroczak *et al.* 2018). Therefore, changes in anthropogenic behaviour in the form of LULC are a significant factor affecting ecosystems (Kijowska-Strugała *et al.* 2018).

Other important factors influencing landscape cover change are climatic conditions. As found by

Spinoni *et al.* (2015b), for the Carpathian region, mean temperature increased between 1961 and 2010, especially during the last three decades. For the same time period, the number of days per year with 40-60 mm of precipitation increased significantly (Bičárová and Holko 2013). There was also an increase in the number of summer days for the entire Carpathian region, as well as a slight decrease in the number of days with frost (Birsan *et al.* 2014). All of these changes put additional pressure on already rapidly changing high mountain regions that are vulnerable to climate change due to differences in elevation (Rangwala and Miller 2012).

The main relevance of this topic and the processing of this issue will be to try to approach and understand the relationships between land cover and the influencing factors that can be observed in high mountain environments in today's rapidly changing environment. Through this research, we can efficiently and quickly process environmental changes over a large area, which is advantageous for assessing changes in ecosystems and natural communities. This research may form a convenient basis for future extension research with the addition of new time horizons.

## Material and Methods

*Study area*

The territory for which we evaluated changes in landscape cover is located in the upper part of the watershed of the Javorinka mountain watercourse. Our entire study area is located in the Belianske Tatry complex in the Tatra mountains, which are part of the Western Carpathians. This water course originates (Zadná Javorová valley) and flows through the entire study area, then continues for 19.3 km into the Biela Voda River as a right-hand tributary before continuing through the Dunajec and the Visla to the Baltic Sea. We functionally separated the environment in which we monitored the changes by the zone of the main ridge, which bounded the given watershed of the Javorinka stream up to the crossing at road number 66 in the village of Podspády (Fig. 1.), where the meteorological station is also located.

From a geological point of view, the study area is one with a diverse structure. Tonalite granodiorites and granites from the Paleozoic, as well as older and younger Carboniferous periods can be found on the southern side of the study area, in the regional part of the High Tatras. Continuing north, following the course of the river, we find limestones and dolomites from the Middle Triassic period. Continuing to the end of the valley, we find claystones, slates, sandstones and quartzites from the younger Jurassic to the older Cretaceous period. Glaciogenic sediments, namely gravel and sand, and deluvial-proluvial sediments, namely gravels and sands, originating in the Pleistocene, can be observed in the riverbed (ŠGÚDŠ 2017). The division of soil types on the basis of altitudinal zonation is as follows: neutral soils dominated by silicate or carbonate elements, alluvial soils with an acid reaction, podzols, cambisols, pararendzinas, rhendzinas, and rankres (Bedrna and Račko 2000). The area is characterised by a cooler climate with continental climate patterns typical of the Alpine climate. In summer (July), the average temperature in the area is 16° C and the total average annual precipitation is 1512 mm (Bičárová and Holko 2013).

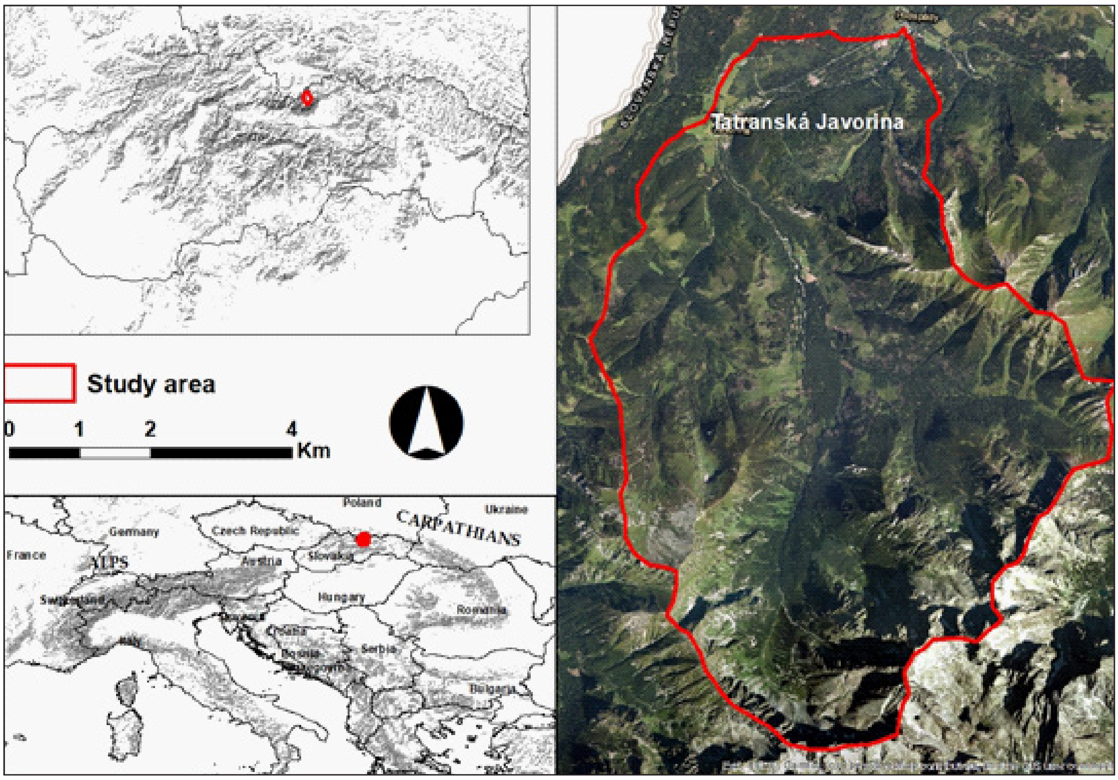


**Fig. 1.** Study area in the watershed of the mountain watercourse Javorinka.

Based on these data, we can also assess that this is a predominantly cold and humid environment.

In our study area there is a village called Tatranská Javorina with population of 172 inhabitants and an area of 9404 ha (ŠUSR 2024). It is a classic type of mountain settlement, not settled permanently until the end of the 18th century (Kollárová 2000). Human activity focused on pasture farming and forestry, followed by industrialisation in the form of charcoal making, metallurgy and production of cardboard (Harvan 1965; Krajčovič 1996; Kollárová 2000). Today, forestry and tourism are the most relevant activities for the area.

Tourism is facilitated by the area's proximity to a State Nature Conservation Authority TANAP. The history of this protected area dates back to 1991, when it was established. This means that in this area human economic activities are limited and there is minimal impact on the landscape, so there is a potential for the natural development of the landscape cover. Therefore, we consider the human impact in the area of the Javorová valley to be moderate.

*Data collection and processing*

To track changes in land cover, we used aerial orthophoto imagery from 2010 with a resolution of 0.5 m per pixel, in addition to images from 2019 with a resolution of 0.25 m per pixel, as we can observe in Table 1. The orthophotos were obtained from the Geodetic and Cartographic Institute Bratislava (GCI). At the same time, we obtained a shape file layer from the National Forest Centre (NFC) that covered the base of our territory and which we also used as the basis of our identification layer. Subsequent work was conducted by ArcMap software (ESRI, USA).

We worked with the S-JTSK Krovak EastNorth coordination system (WKID: 5514). Our procedure consisted of a sequential manual identification of individual images based on the time horizons. After creating a complete documentation of the entire study area, we transformed the given shape file vector layer into a raster, from which we subsequently extracted the necessary environmental data for the two horizons under study. We processed the results using the raster calculator function in ArcMap software.

Our manual editing resulted in two shape file layers, within which we assigned the necessary identification to the individual polygons that represented the functional elements in the landscape cover in the form of a code designation, which can be seen in Table 2. This subdivision of the individual landscape features is based on the Corine Land Cover (CLC) change manual that we produced in level three for our study area (EEA 2019). We only made minor changes in the Forest subgroup where we added the health and young forest elements, in the Shrub and/or herbaceous vegetation associations subgroup we replaced the original Transitional woodland/shrub with a value of 324 with

| Years | Background materials | ∑ LMS | Resolution | Colour | Pixels |
|---|---|---|---|---|---|
| 2010 | Aerial measurement photography | **14** | 1200 DPI | RBG | 0.50 |
| 2019 | Aerial measurement photography | **8** | 1200 DPI | RBG | 0.25 |

**Table 1.** Time horizons and their background materials.

| ID | Group of elements | ID | Subgroup of elements | ID | Elements |
|---|---|---|---|---|---|
| 1 | Artificial surfaces | 11 | Urban fabric | 111 | Continuous urban fabric |
| | | | | 112 | Discontinuous urban fabric |
| | | 12 | Industrial, commercial and transport units | 121 | Industrial or commercial units |
| | | | | 122 | Road and associated land |
| | | 14 | Artificial, non-agricultural vegetated areas | 141 | Green urban areas |
| | | | | 142 | Sport and leisure facilities |
| 2 | Agricultural areas | 24 | Heterogeneous agricultural areas | 242 | Complex cultivation patterns |
| 3 | Forest and seminatural areas | 31 | Forest | 31a | Health forest |
| | | | | 31b | Young forest |
| | | 32 | Shrub and/or herbaceous vegetation associations | 321 | Natural grassland |
| | | | | 322 | Moors and heathland |
| | | | | 324a | Damaged forest |
| | | | | 324b | Dry or dead forest |
| | | 33 | Open spaces with little or no vegetation | 332a | Bare rock - compact |
| | | | | 332b | Bare rock - debris |
| 5 | Water bodies | 51 | Inland waters | 511 | Water courses |
| | | | | 512 | Water bodies |

**Table 2.** Distribution of classified classes based on the CLC classification of the 3rd degree with a modified matrix (EEA 2019).

the damaged and dry or dead forest elements, and to the Bare rocks element, which we additionally subdivided even further into the Compact rock and Rock debris elements. The reason for these changes was to try to fit partitioning closer to our observed elements, while at the same time maintaining more detailed partitioning in the structure of these classes, in an attempt to preserve the original partitioning as much as possible.

After developing the necessary shape file layers for the two-time horizons under study, we started the calculations. For these we mainly used the Raster calculator tool in ArcMap Desktop software in addition to Microsoft Excel for working with spreadsheets and small calculations. We extracted the actual figures from the attribute table of the layers. At the same time, using an external Change detection tool (UNIBA 2016) that we embedded in our Toolbox, we completed Gain and Loss and Net change graphs. After selecting the individual elements into separate layers, we were able to focus more closely on comparing their fluctuations between years.

## Results

Within our study area, there have been noticeable changes in land cover over the 9-year period. As we can see in Table 3., the least altered area was in the vicinity of human habitation, where no significant changes occurred over this period. The only noticeable change in the Artificial Surfaces category occurred for the Roads and Associated Land category, where there was a 0.02% increase in area, roughly a difference in area of 1.31 hectares. This is also visible in the increase in the intensity of roads on the landscape cover that was exposed after the breakdown of the forest community. Otherwise, there was no change in the Artificial Surfaces group, so it will be the least discussed. For the Forest and semi-natural areas group, on the other hand, we observed the most significant changes, reflected in a significant decrease in the area of healthy forest and an increase in the area of young forest, together with an increase in dry or dead forest. The area of healthy forest, which in 2010 was still at 1864.19 hectares, has decreased to 1527.41 hectares, a percentage change of up to -7.11%. The substantial increase in the damaged forest group would explain this strong decline in the healthy forest, as there was an increase of 5.05% in this group, which amounts to an increase in area of 239.28 hectares. At the same time, the replacement of dry or dead forest by young forest was also visible, where a young generation of trees must have taken hold during the period under review. Thus, there was also an increase of 3.19% in the area of young forest and an increase of 151.38 hectares, while the area of the dry or dead forest group increased only slightly by 0.57% (27.18 hectares). Overall, the Forest group was the most affected by the changes during the study period, and we observed a gradual transformation of this forest community. However, indications of its decay are accompanied by an increase in the young generation of trees, which indicates a gradual and relatively rapid regeneration response in this group.

Another interesting result is the changes taking place at higher altitudes in the natural grassland and moors and heathland - *Pinus mugo* groups. For both of these classes we observed a small decrease in area over the period; natural grassland showed a decrease of 1.07% and 50.64 hectares, the moors and heathland group - *Pinus mugo* experienced a decrease of

| Code | Category | 2010 in ha | 2019 in ha | Change in ha | 2010 in % | 2019 in % | Change in % |
|---|---|---|---|---|---|---|---|
| 111 | Continuous urban fabric | 1.04 | 1.26 | 0.21 | 0.02 | 0.03 | 0.01 |
| 112 | Discontinuous urban fabric | 0.35 | 0.34 | 0.00 | 0.01 | 0.01 | 0.00 |
| 121 | Industrial or commercial unit | 5.02 | 4.81 | -0.20 | 0.11 | 0.10 | -0.01 |
| 122 | Road and associated land | 15.44 | 16.76 | 1.31 | 0.33 | 0.35 | 0.02 |
| 141 | Green urban areas | 4.00 | 3.85 | -0.15 | 0.08 | 0.08 | 0.00 |
| 142 | Sport and leisure facilities | 0.14 | 0.17 | 0.03 | 0.00 | 0.00 | 0.00 |
| 242 | Complex cultivation patterns | 4.30 | 4.36 | 0.07 | 0.09 | 0.09 | 0.00 |
| 31a | Health forest | 1864.19 | 1527.41 | -336.77 | 39.38 | 32.27 | -7.11 |
| 31b | Young forest | 112.44 | 263.82 | 151.38 | 2.38 | 5.57 | 3.19 |
| 321 | Natural grassland | 773.44 | 722.80 | -50.64 | 16.34 | 15.27 | -1.07 |
| 322 | Moors and heathland (PM) | 665.77 | 640.44 | -25.32 | 14.06 | 13.53 | -0.53 |
| 324a | Damaged forest | 331.18 | 570.47 | 239.28 | 7.00 | 12.05 | 5.05 |
| 324b | Dry or dead forest | 77.43 | 104.61 | 27.18 | 1.64 | 2.21 | 0.57 |
| 332a | Bare rocks - compact | 526.13 | 512.93 | -13.20 | 11.11 | 10.84 | -0.27 |
| 332b | Bare rocks - debris | 320.79 | 318.54 | -2.26 | 6.78 | 6.73 | -0.05 |
| 511 | Water courses | 27.81 | 36.52 | 8.71 | 0.59 | 0.77 | 0.18 |
| 512 | Water bodies | 4.41 | 4.78 | 0.37 | 0.09 | 0.10 | 0.01 |
| Σ | Total | 4733.88 | 4733.88 | | 100.00 | 100.00 | 5.05 |

**Table 3.** Table of results of all land cover classes in the time horizon 2010 - 2019.

0.53% and 25.32 hectares. However, spatial distribution is also important for these classes because as we also observed changes in their vertical distribution.

Both compact rock formation and those with debris character experienced a small reduction in area, namely for compact rock formations (0.27%) and for debris (0.05%). On closer comparison of the maps at each time horizon, it was noticeable that rock debris regularly appears, but loses area with time and succession of the surrounding vegetation. For watercourses and water bodies, there was an increase between time horizons for both the watercourse group (0.18%) and the water body group (0.01%).

In Figure 2. we can observe significant changes in forest elements. The largest decrease in area was recorded in the healthy forest element (31a), which is explained by the largest increase in the damaged forest element (324a). At the same time, there was a decrease in the area of the damaged forest element and an increase in the area of the young forest element. This points to a natural cycle of regeneration of felled or calamity-affected forest, where, after the breakdown of the old tree structure, a new generation filling a given damaged ecotone immediately takes over when the area is cleared and the level of competition for sunlight is reduced. As for the area of the dry or dead forest element (324b), there was an overall increase in its area, although the gains were not greater than the losses. For other elements we can observe that the number of increments did not exceed the amount of lost area, which we observe for moors and heathland - *Pinus mugo* community (322), and natural grassland, which represents alpine meadow communities.

In Figure 3., we can clearly see that in the environment we studied, the area of healthy forest was reduced by more than 300 hectares, while young forest had an increase of more than 100 hectares and damaged forest by more than 200 hectares. For the slash and alpine meadow elements, we observe a trend of decline in area, which we subsequently link to the abiotic factor in the next chapter. At the same time, there has been a slight increase in the area of dry or dead forest and a negligible increase

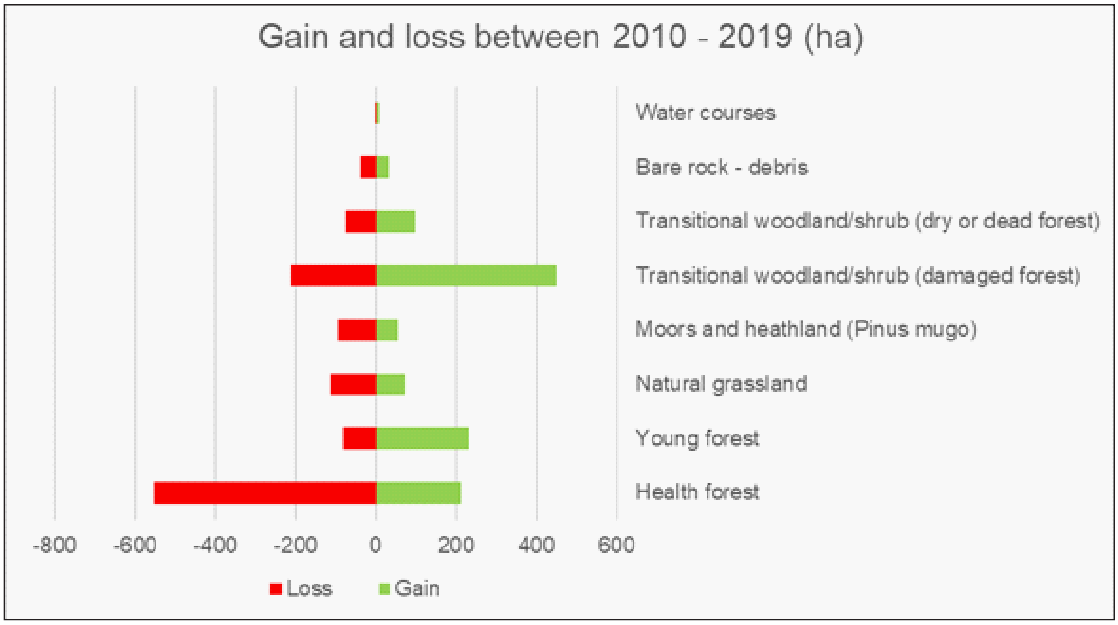


**Fig. 2.** Graph of increases and decreases in hectares in the observed horizon 2010-2019 for selected classes with significant change.

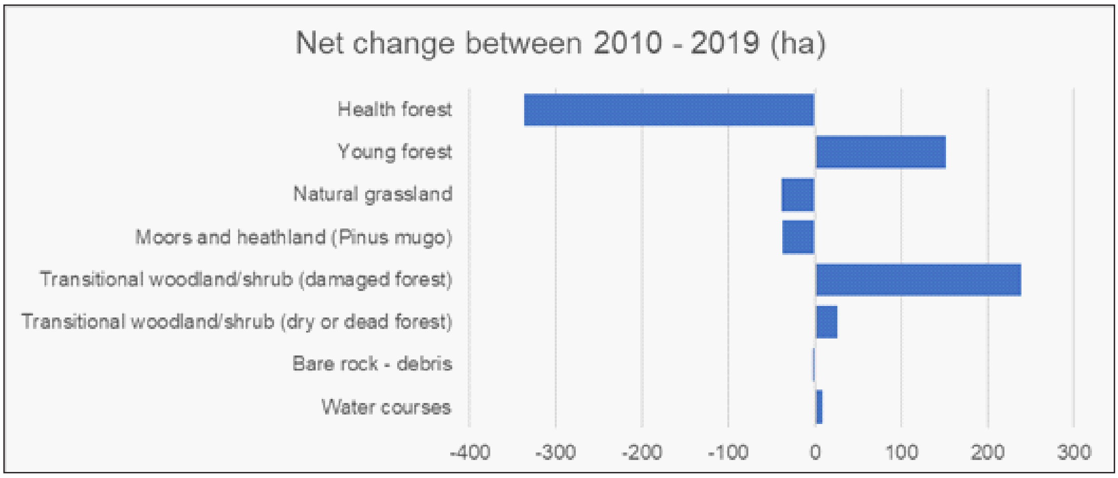


**Fig. 3.** Graph of the net increase in area in the time horizon 2010-2019 for selected elements with a notable change.

in the area of watercourses for the size of the area we are looking at. This tells us a great deal about the events that have taken place in the years under study, as such an increase in area for watercourses is unusual for such an abbreviated period of time.

## Discussion

Our work traces the development of natural units in connection with man in the closed, mostly north-oriented valley of the upper part of the Javorinka river basin. It is changes in rural areas that can reveal both natural and socio-economic trends. Confirming the general trend of urbanization and population transfer from rural to urban environments (Zhang 2008; Karcagi-Kovats and Katona-Kovats 2012), our study area is also involved in these socio-economic processes. Given that much of the land in this area is owned by the state and also that the subsequent inheritance of land has led to a very strong fragmentation of land ownership, it is already difficult to start either entrepreneurial or residential activities for this reason (Van Dijk 2007). Land acquisition from the state and land consolidation could be a solution, but both of these options are time and cost consuming and in practice we see that they do not work to the extent that would be needed for the social resuscitation of the countryside. We found it was artificial surfaces classes that changed minimally, if at all, over the time period under review. This only confirms the overall trends in the underdevelopment of rural communities in the high mountains (Lun *et al.* 2016). The element undergoing the greatest change among artificial surfaces was the road and associated land element with an increase of 0.2% between horizons. This increase could be explained by the revelation of a larger area of forest land, where, after the forest community decay and the transition from healthy forest to damaged forest element, a better view opens up on the ortophoto maps of the road network, which may have been hidden under the tree canopy in 2010 and therefore could not even be identified as it was already possible on the revealed surfaces in 2019.

For industrial sites, we observed the departure of businesses such as the state-owned timber sawmill, where the building itself was demolished and operations ceased. A typical trend in such areas is a change in the age structure of the population, where there is a noticeable aging of the community and the departure of younger generations to the nearest urban areas (Ira 2003; Podolak 2005). Subsequently, we are witnessing a decrease in the permanent population in the given area over the last 19 years, whereby the population of the Tatranská Javorina village decreased by 24.5% (ŠUSR 2024). We consider this to be overwhelmingly negative, as the younger generation could begin to cultivate conditions that promote soft tourism. Soft tourism has proven to be the best option for making a living in rural areas that does not have the direct negative impact on the environment that hard tourism does (Belsoy *et al.* 2012). Within the transition history of the area, which has been characterized by predominantly mining and forestry, this would be the onset of a positive trend in terms of environmental impact.

Elements that received less attention included watercourses and reservoirs, where minor change has occurred compared to forest communities. It is important to note, however, that substantial changes are not expected for these elements, and even the incremental change documented over the 9-year period can be assessed as significant changes. The area growth of water bodies can be explained by temporal differences between the ortho photomaps over a period of one year, with the 2010 image taken in June and the 2019 image taken in August. Thus, it is possible that in June, snow remnants may still have masked the actual edges of water bodies, whereas in August they stood out clearly and with a larger area. However, Kapusta *et al.* (2021) point to a long-term reduction in the area of tarns in Slovakia and Poland, including two tarns from our study area, which showed a reduction in area between years. We observed the emergence of a new water area near the village of Tatranská Javorina, where a water area was added on the site of a former state sawmill,  absent in 2010. We evaluate this factor as the main cause of the increase in the area of water bodies in our territory. When observing changes in watercourses, we must also focus on the specifics of our study area. Ortyl *et al.* (2018) point out the strong connection of the landscape with the river system, where post-war trends such as depopulation of the landscape, coupled with the reduction of the area under economic use, leads to its overgrowth by shrubland and subsequently by forests. This has the direct consequence of stabilising slopes, reducing sediment loads on rivers, and lowering average water levels. In this process, we subsequently observe a deepening of the riverbed, and progressively greater changes in the river channel. In our case, however, we observed an increase in the area of the river channel (8.71 ha). A possible explanation for this would be the flooding that took place in 2018 when areas of the surrounding banks were swept away, along with significant sediment scouring and changes in water flow. Similar conclusions regarding the impact of flooding on small catchments in mountainous environments have been drawn by Bucała-Hrabia *et al.* (2020), who pointed out that there was a very similar flood on the Polish side of the Tatra Mountains in the same period, resulting in significant changes affecting the unmodified sections in the river channel.

In our study area, there was a 0.53% decrease in *Pinus mugo* shrub acreage across the entire study catchment over the study period, which is not consistent with the general trend in the Western Carpathians (Švajda *et al.* 2011; Parobeková *et al.* 2018; Žoncová *et al.* 2020) or, more broadly, in Central Europe as a whole (Palombo *et al.* 2013). One reason for this may be that a time horizon of 9 years is too short to show longer-term trends, where we see that other authors focusing mainly on *Pinus mugo* shrubs have worked with time horizons of several decades (Solár and Janiga 2013; Parobeková *et al.* 2018; Calabrese *et al.* 2018). Overall, however, we were able to detect a general trend of increasing *Pinus mugo* abundance as a function of elevation, with the elevation range shifting vertically upwards by less than 3 m on average across the study area. This is only a small shift, but the observation horizon was also only 9 years. At the same time, however, we can state that the overgrowth of the alpine meadow by *Pinus mugo* stands was more than evident in several places, especially when observing small islands, the appearance of new islands, and the overgrowth of old gaps in the larger *Pinus mugo* patches. As described by Dullinger *et al.* (2003), the matrix of herbaceous vegetation at the upper edge of the *Pinus mugo* distribution is also important for the shift to higher elevation in the case of the alpine shrubs zone. In comparison, Tesei *et al.* (2022) discuss the species richness of alpine vegetation at sites after *Pinus mugo* dieback. Zeidler *et al.* (2018) produced the same result, but they observed species richness at a site where *Pinus mugo* was not native and mostly populated by rare transitional herbs.

Looking at landscape cover changes across the study area, we can see that the area of rock scrub increased between time horizons. This could be explained by the rock slides that we observed in several places in our study area. This area has been previously described in more detail in terms of the significant occurrence of soil detachments and rock avalanches (Boltižiar 2009). However, what might stand against this case, is the progression of vegetation succession in several locations of former rock debris, where partial or even complete overgrowth of rock debris by herbaceous vegetation has occurred.

During the period under review, we witnessed degradation processes of forest communities, the emergence of which can be explained by a number of factors. As reported by Root *et al.* (1977), areas were planted in the Javorová valley that previously had no forest cover. Failure to maintain the diversity structure of this forest may result in its future degradation. At the same time, the bark beetle factor, which in constructive interaction with other factors causes the breakdown of the forest community (Mezei *et al.* 2014), should highlighted as part of the natural regeneration of the forest (Winter *et al.* 2015). Among these factors, even solar radiation emerges as a capable predictor, with Mezei *et al.* (2019) pointing to the spread of bark beetles in forest patches with elevated solar radiation. However, the acute drought stressor as a stressor of forest vegetation is also discussed by Netherer *et al.* (2019), where they show exactly how, in the Austrian Alps, sites with an elevated stress factor from drought were increasingly invaded and degraded by bark beetles. This would correspond to our case, and align with Janda *et al.* (2017) who observed that forests of the Western Carpathians carried a certain predisposition from former disturbances, where the age structure and size of the forest stand were homogenized. Lausch *et al.* (2011), in turn, noted the importance of the proximity index or tree density in forest structure; the denser, the higher the incidence of bark beetles. As shown by Žoncová *et al.* (2020), monoculture forests artificially planted on north-facing hills of the Low Tatras have succumbed to rapid degradation, which may serve as an example of inappropriate forest management. Today, in order to effectively maintain the necessary biodiversity and stability of the forest community, it is necessary to put aside preconceived notions and focus on the knowledge gained from both forestry and research perspectives.

Similar cases with sudden overpopulation and rapid range expansion of *Ips typographus* are also observed in northern areas in the nature reserve in the Arkhangelsk region of Russia. In tracing forest community change over a period of more than a decade, the combination of mean annual temperature and precipitation, together with temperature and precipitation in the month of June, have been identified as the leading factors for the spread of this crustacean (Trubin *et al.* 2022). Bark beetle spreads not only in protected areas, but also throughout forests harvested by the logging industry. In this case, it is particularly important to understand the methodology of its dispersal. In the Polish Tatra Mountains, where Sproull *et al.* (2017) focused precisely on its distribution over two decades, they assessed that tree mortality in both management and protected areas increased significantly over the period studied, precisely because of bark beetle. Interestingly, however, they assessed efforts to slow its spread in management forests as ineffective. They also identified altitude and solar radiation as possible, albeit less effective predictors of the species' distribution.

## Conclusion

Within the study site, relatively significant changes in landscape cover elements have occurred during the time horizon under study. The most negatively impacted elements were the healthy forest, natural grassland, and moors and heathland (PM) classes. Elements that increased their area included damaged forest, young forest, and dry or dead forest. Evidently, the forest community in the study catchment is undergoing significant structural changes. We do not expect this trend to cease in the coming years and expect further increases to area of damaged forest and dry or dead forest. On a positive note, the strong emergence of a young generation of trees is taking its place in rapid succession in the areas of damaged forest. It would be useful to take a closer look at the changes in the alpine belt, where we observed slight decreases in the area of the elements. We relate this to a possible gradual overlap of bioclimatic horizontal zones, where it is possible that a gradual change in environmental conditions is increasing the mean elevation of the species' occurrence. Changes in landscape cover give us significant insight into the landscape, and can effectively be used to monitor and raise awareness of the importance of these changes.

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