Remote sensing and GIS in research of geoecological processes

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Abstrakt. Diaľkový prieskum a geografické informačné systémy vo výskume geoekologických procesov. Zmeny vo využití zeme a geoekologické procesy sú vo vysokohorskom prostredí úzko previazané. Pôdnu a rastlinnú pokrývku priamo ovplyvňujú intenzívne morfogenetické procesy. Vyhodnotenie ich priebehu a intenzity je možné s využitím leteckých fotografií. Ako základ pre geoekologický výskum v Národnom parku Malá Fatra boli použité ortofotomapy z rokov 1992-2003, zachytávajúce miesta s poškodenou pôdnou a rastlinnou pokrývkou. V prostredí GIS bolo tiež vytvorených niekoľko modelov priestorového rozšírenia morfogenetických procesov, čo spolu s terénnym výskumom umožnilo podrobnú morfogenetickú analýzu v skúmanom území. Na základe takto získaných výsledkov bola vytvorená mapa morfodynamických systémov, využiteľná pri manažmente chráneného územia.

Kľúčové slová: letecká fotografia, pôdna a rastlinná pokrývka, diaľkový prieskum, model, GIS.

Abstract. Landuse change and geoecological processes in the alpine environment are closely tied. Geoecological processes, especially morphogenetic ones, affect the soil and vegetation covers. Presented geoecological research was done in Malá Fatra National Park in Central Slovakia. The evaluation of course and intensity of morphogenetic processes was based on analyses of aerial photographs and modeling. Orthophotomaps from period of 1992-2003 were used for identification of areas with soil and vegetation covers disturbed by intensive morphogenetic processes. Several models, simulating distribution of morphogenetic processes in GIS environment, were developed. These models, together with field research, enabled detailed morphological analyses. The results from different analyzed slopes led to creation of a map of spatial distribution of morphodynamic systems. Resulting map is usable for management of protected area.

Keywords: aerial photographs, soil and vegetation covers, remote sensing, model, GIS.

1 Introduction

The presented research focuses on recent geomorphological processes and their influence on soil and vegetation covers in the environment of artificial alpine meadows of Western Carpathians. The aims of the research are as follows: to map the spreading of recent morphogenetic processes using field research, remote sensing techniques and computer modeling, to evaluate the course and intensity of morphogenetic processes and finally to evaluate the distribution of morphodynamic systems within selected areas.
Two testing regions, situated in Krivánska Malá Fatra Mts., Central Slovakia, were chosen to study in (Fig. 1). They occupy southern and southeastern slopes of the mountains, between upper timberline and the main ridge, covered mostly by artificial alpine meadows, partly by dwarf pine. Artificial meadows were created during Wallachian (sheperd) colonization in 15th-17th centuries. Deforestation led to increase of intensity of geomorphologic processes and intensive soil erosion above upper timber line. The selected areas are almost of the same size, together covering 279 ha. The elevation varies between 1,032 and 1,671 m a. s. l. and predominant inclination is 30-35º. Both areas cover south and south-east slopes of the Malá Fatra main ridge. The two testing regions were chosen to enable comparison of morphodynamic processes on grazed and ungrazed slopes (Fig. 1).

2 Methods

Methods used during research partly consist of computer based modeling, spatial analysis, input maps interpretations and field observations. ArcView GIS and GRASS GIS were the most often used geographic information systems. Topographic maps at a scale of 1:10,000, geological map (1:50,000), Avalanche cadastre (maps of avalanche paths) and schemes of landslides were among the input maps.

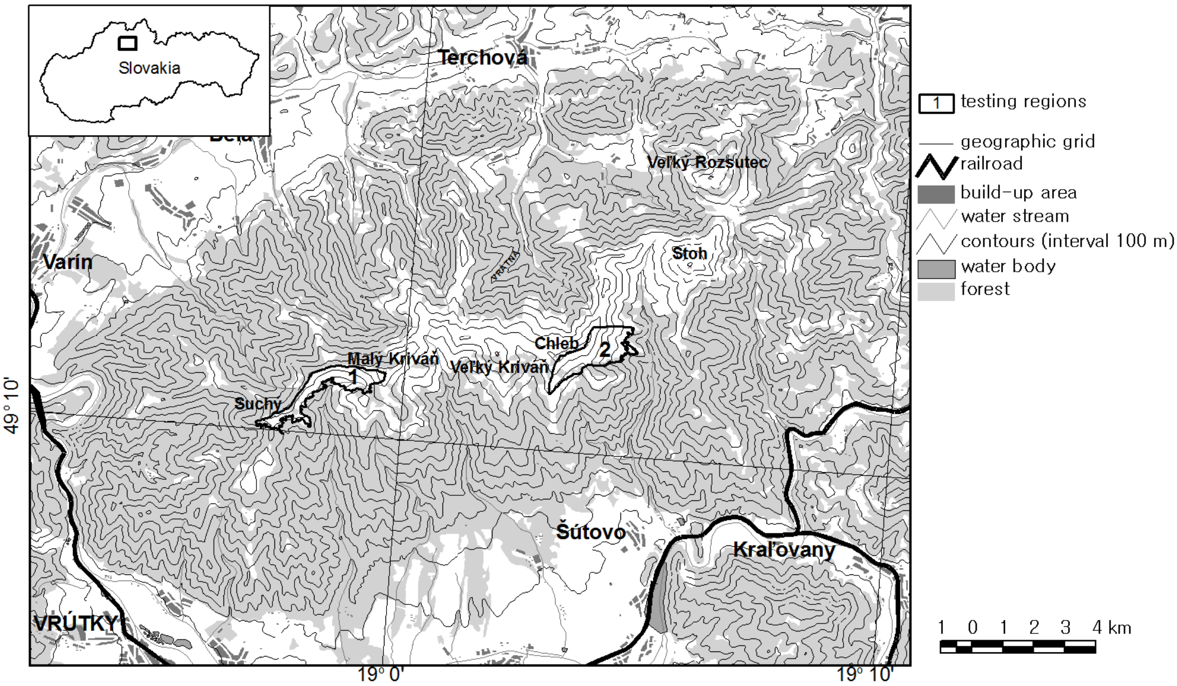

Fig. 1. Location of testing regions.

Several maps were created using different algorithms to evaluate potential distribution of recent geomorphological processes: geomorphological landforms, potential soil erosion, actual erosion and deposition (according to USPED model), susceptibility to gelifluction, avalanche activity and morphodynamic systems. All of the maps computed by models were verified by field research and interpreted orthophotomaps. Two orthophotomaps were prepared by ortorectification of monochromatic aerial photos (taken in 1992) and compared with color orthophotomaps (from 2002, 2003 res.) to evaluate the state of the soil and vegetation covers within these years. Field research was focused on chosen localities where processes were easy to identify and possible to evaluate their influence.

Interpretation of aerial photographs. The distribution of disturbed vegetation and soil covers was evaluated by interpretation of the aerial photographs. Grey-scale images from 1992 were orthorectified within GRASS Open Source GIS software [14] using modul i.ortho.photo. Digital elevation model, computed for orthorectification, was based on vectorised contours from topographic maps at a scale of 1:10 000. The resolution of resulting orthophotomaps was 0.6 m. It was suitable for identification of erosion landforms with size equal or greater than 1 m. The true-color orthophotomaps from the years 2002 and 2003 were prepared by company GEODIS Slovakia s.r.o. The vegetation and soil covers were classified into 3 classes depending on the coverage (>85% not disturbed, 15-85% disturbed and <15% destroyed). True-color orthophotomaps were classified into these classes by supervised image classification and maximum likelihood method (modules i.class and i.maxlik within GRASS). Training datasets, representative of the cover classes, were selected within the images. Their spectral signatures were computed, which allowed classification of the maps. The grey-scale orthophotomaps were only reclassified according to brightness of the surface as the color bands in the images were missing. Continuous vegetation cover was displayed in dark colors and disturbed or destroyed vegetation in lighter ones. The training data sets were hard to select due to the 15 years delay since the images were taken, so some other process had to be chosen. True-color maps from 2002 and 2003 were converted into the gray scale and the difference in brightness within each category was computed and applied to the maps from 1992. The areas with totally destroyed vegetation and soil covers were the base the differences were applied from. Only two slopes within testing regions were chosen for evaluation of changes in disturbance of vegetation and soil covers (Fig. 2). As the terrain roughness within the evaluated slopes is very low, the presented process should be accurate. The resulted maps showed distribution very similar to the schematic map of soil destruction published by Midriak [10].

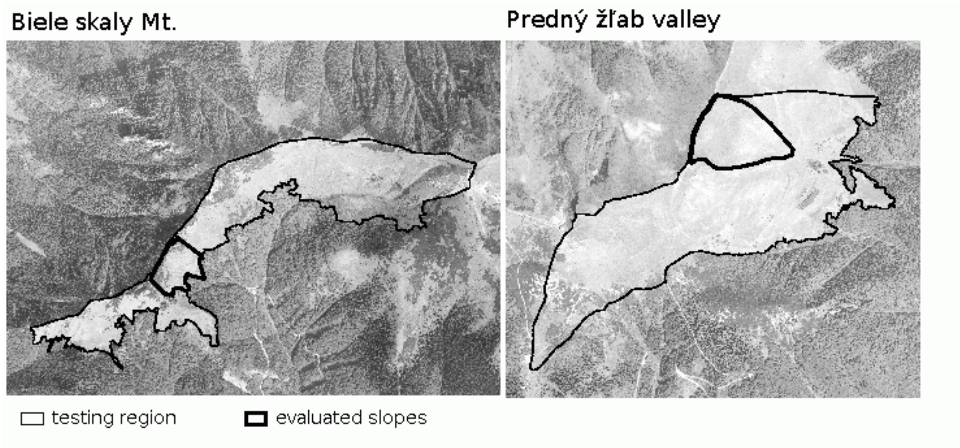

Fig. 2. Location of slopes with evaluated distribution of disturbed areas.

Map of destructiveness of the soil by runoff processes. The method of evaluation of the soil destructiveness was developed by Janský and Bedrna ([6], [4]). It is based on K-coefficient known from universal soil loss equation [17]. Destructiveness is understood as a susceptibility to destruction in relation with surface inclination [4]. The map of inclination derived from DEM was classified into 6 classes according to Klečka et al. [7]. The soil types and subtypes were given K-factor values according to Bedrna [4]. Combinations of inclination classes and K-values were created and classified into 3 classes of destructiveness (Fig. 3a).

Map of potential soil erosion. The potential soil erosion was evaluated using method of Stehlík [16] based on Frevert-Zdražil's equation [19]. Input data to equation are as follows: rainfall intensity, rock types, soil properties (texture and humus content) and slope inclination. The model equation is a simple multiplication of these four factors. The raster maps of the factors with resolution of 3 m were multiplied using map algebra. The result is potential soil loss in mm of soil profile (Fig. 3b).

Map of erosion and deposition by runoff processes. Spatial distribution of water erosion and deposition was estimated by USPED model (Unit Stream Power – based Erosion Deposition, [12], [11]).

$$T = R \cdot K \cdot C \cdot P \cdot A^m \cdot (\sin b)^n, \quad (1)$$

where *T* is transport capacity, *R* rainfall erosivity factor, *K* soil erodibility factor, *C* cover and management factor, *P* support practice factor, *A* upslope contributing area, *b* slope and *m*, *n* are constants (m=1.6, n=1.3 for prevailing rill erosion while m=n=1 for prevailing sheet erosion). There is only one active gully in the testing regions; therefore the values of *m* and *n* were set to 1. *P* factor was omitted during computation (*P* = 1) because no support practices are applied in testing regions. R factor was not spatially differentiated so it had no influence to distribution of erosion and deposition. No experimental work was performed to develop parameters needed for USPED [13] so the factors values from USLE, calibrated for the Central Europe conditions ([9], [5]), were used. The C factor value for vegetation of alpine meadows was given according to Passák [15] and the value for dwarf pine was lowered 10 times comparing to meadows [10]. The boundaries of polygons with different K factor values were smoothed using linear function as the real boundaries of soil types are not sharp. The computed maps should be considered only as relative values due to mentioned problems (Fig. 3c).

Map of susceptibility to gelifluction. Slope inclination and soil texture were used as inputs for computation of susceptibility to gelifluction. Gelifluction means the slow, continuous downslope movement of rock debris and water-saturated soil that occurs above frozen ground. Therefore the types of rocks were not included into computation. The values of the factors included were set according to Lukniš [8], Bedrna [4] and results of the field research in testing regions. The final map of susceptibility to gelifluction was developed as a combination of input factors' categories and their reclassification [2]. It displays relative potential of soil cover to gelifluction process and initiation of gelifluction landforms (Fig. 4). The gelifluction can act after the vegetation has been disturbed by deforestation and overgrazing. The applied method was developed to conform to conditions of testing regions and its application in other conditions would need some modifications.

Map of landforms. Morphometric features (peaks, ridges, passes, channels, pits and planes) were identified from DEM using GRASS module r.param.scale [18]. The module is scale-dependent and uses a multi-scale approach by taking fitting quadratic parameters to mowing window. It was applied with slope tolerance of 5° (defines flat surface), curvature tolerance of 0.005 (defines planar surface) and window-size of 45 m. The landforms, identified with these values of input factors (Fig. 5), conform to influence of terrain to distribution of snow cover as observed during winter seasons. The planes (slopes) covered the most of testing regions; therefore they were reclassified into 3 classes (gentle 0-20°, moderate 20-35° and steep slopes 35-90°) for presentation purposes.

Map of avalanche activity. Field research and avalanche cadastre (maps of avalanche paths) prepared by Avalanche Prevention Centre in Jasná were used as a basis for creation of map of avalanche activity. The avalanche paths from cadastre's maps at a scale of 1:10 000 were vectorised and modified according to field research and orthophotomaps. The modification was necessary because of inaccurate representation of observed paths in original maps and reforestation of some localities since last update of cadastre's maps. The localities with vegetation and soil disturbed by avalanches were mapped during field research.

Map of morphodynamic systems. This map was developed as a combination of several other maps: map of landforms, map of avalanche activity, map of gravitational processes, map of water streams and map of hiking trails. The slopes were compound into one category, avalanche paths were classified into two categories (paths with and without disturbed vegetation and soil). Map of gravitational processes was reclassified into two categories according to the type of gravitational slope deformation. The maps were overlaid in raster form using GRASS module r.cross and individual categories were reclassified according to Table 1. Hiking trails were marked as linear anthropogenic morphosystems and water streams as linear fluvial morphosystems. The names of morphosystems were arranged with increasing dominancy of geomorphic processes from left to right; it means the most important process is situated at the end of the name.

Table 1. Morphodynamic systems as a combination of dominant geomorphic processes

Landform	Gravitational processes	Avalanche path with vegetation and soil	Morphodynamic system
slope	-	-	runoff
slope	-	not disturbed	avalanche-runoff
slope	-	disturbed	runoff-avalanche
slope	creep / stabilized landslide	-	gravitational-runoff
slope	creep / stabilized landslide	not disturbed	gravitational-avalanche-runoff
slope	creep / stabilized landslide	disturbed	gravitational-runoff-avalanche
slope	creeping debris	-	runoff-gravitational
valley bottom	-	-	fluvial-runoff
valley bottom	-	not disturbed	avalanche-fluvial-runoff
valley bottom	-	disturbed	fluvial-runoff- avalanche
valley bottom	creep / stabilized landslide	-	gravitational-fluvial-runoff
valley bottom	creep / stabilized landslide	not disturbed	gravitational-avalanche-fluvial-runoff
valley bottom	creep / stabilized landslide	disturbed	gravitational-fluvial-runoff-avalanche
valley bottom	creeping debris	-	fluvial-runoff-gravitational
saddle	-	-	aeolian
ridge	-	-	aeolian-runoff
ridge	-	not disturbed	avalanche-aeolian-runoff
ridge	-	disturbed	aeolian-runoff-avalanche
ridge	creep / stabilized landslide	not disturbed	gravitational-avalanche-aeolian-runoff
ridge	creep / stabilized landslide	disturbed	gravitational-aeolian-runoff-avalanche
Peak	-	-	aeolian

3 Results

The most intensive processes in alpine meadows are avalanche activity, runoff processes, gelifluction and needle ice growth. The slopes of the testing regions are very susceptible to soil erosion (Fig. 3a). Runoff influences soils of the testing regions stronger than any other geomorphic process. Only several thousands of square meters with flat surface have lower susceptibility. Most of the area has very strong or strong potential erosion. A bare soil on steep slope can be completely removed by water erosion within several years. Vegetation cover is the only one protecting the soil, thus all of the places without vegetation are exposed to sheet and linear runoff processes; however the deepest active gully is only 1.1 m deep and 0.5 m wide.

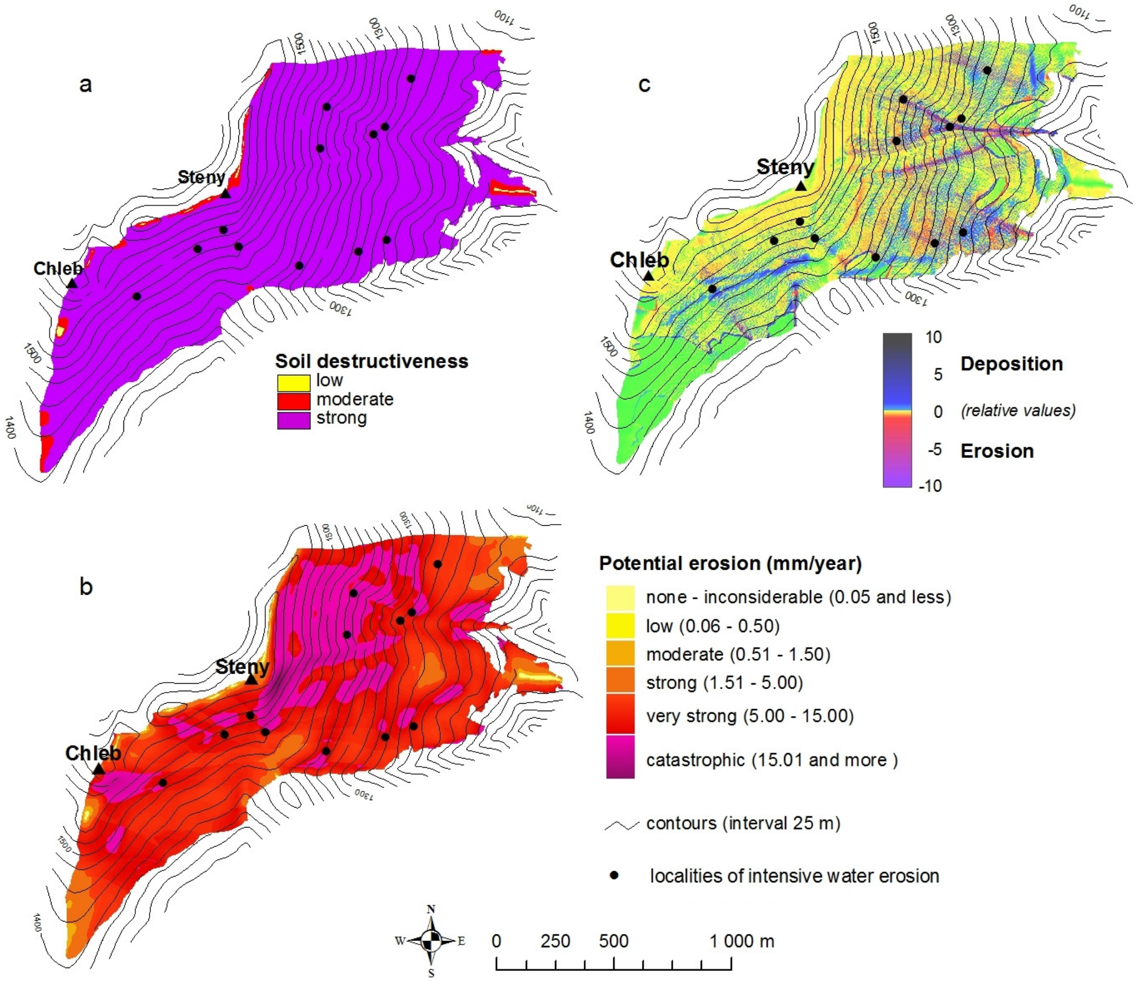

Fig. 3. Destructiveness of soil (a), potential soil erosion (b), erosion and deposition by runoff processes (c) and localities of intensive water erosion according to field observation in testing region 2.

There are very few places in both testing regions where soil was completely removed. After the removal of fine particles of the upper soil horizons the pavement of stones and gravel (usually greater than 3 cm in diameter, but depending on steepness of the slopes) protects the underlying lower part of soil profile from removing. In this stage the vegetation can gradually recover. Hiking trails and slopes with intensive avalanche activity (which disturbs vegetation) are typical place of intensive runoff processes.

The two maps expressing the potential for erosion (Fig. 3a, 3b) show high susceptibility of soil cover to water erosion. Potential erosion and destructiveness do not include the factor of vegetation, thus the results of these models depend predominantly on the inclination and soil properties. Incorporation of the vegetation factor (Fig. 3c) enabled the visualization of the importance of vegetation cover in alpine environment. However the field research results showed that even bare soils on 30º steep slopes were not completely removed if soil stoniness was high.

Gelifluction acts during each spring season (april-june) and typically creates cracks in hiking and cattle paths or on the slope (up to 17 cm wide). This process is wide-spread within testing regions but its intensity is low. The spring cracks in soil and slowly slides of individual clumps of vegetation are the only observed cases of active gelifluction forms (Fig. 4).

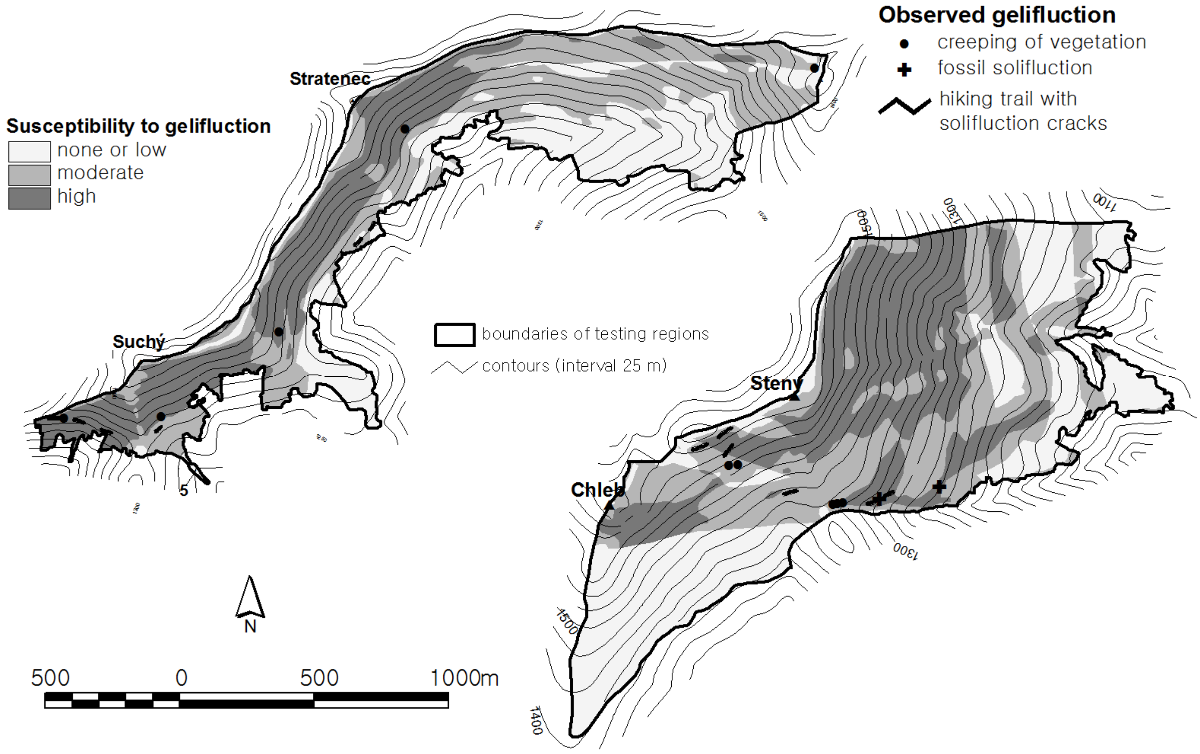

Fig. 4. Susceptibility to gelifluction.

Avalanche activity affects 53% of testing regions. There were 98 localities with soil and vegetation covers disturbed by avalanches, mapped during field research. Accumulation of transported material often takes form of ramparts, up to 2 m high and 16.8 m long. Nivation, although not intensive, led to creation of one nivation bench 300 m long, still formed by snow fields. Gravitational processes in the form of creeping, cambering, landsliding, debris fall and debris flows affect some parts of model areas (app. 1/3), but mostly in the form of inactive, stabilized landslides. The modeling of avalanche activity was the object of the author's previous research ([3], [1]).

Anthropogenic morphodynamic processes are closely tied with cattle grazing. The effects of grazing and trampling on georelief ended in model areas in 2000 (end of the grazing in testing region 2). Slowly vanishing trampling paths cover 1/3 of model areas. They are still visible on steepest slopes after the 30 years from the end of grazing in testing region 1.

Besides the influence of geomorphic processes on soil and vegetation, the strong dependency was observed between type of vegetation and distribution of geom. Processes (Barka 2005). It is probable that influence of vegetation on geomorphologic processes is more intensive than vice versa (in the conditions of testing regions).

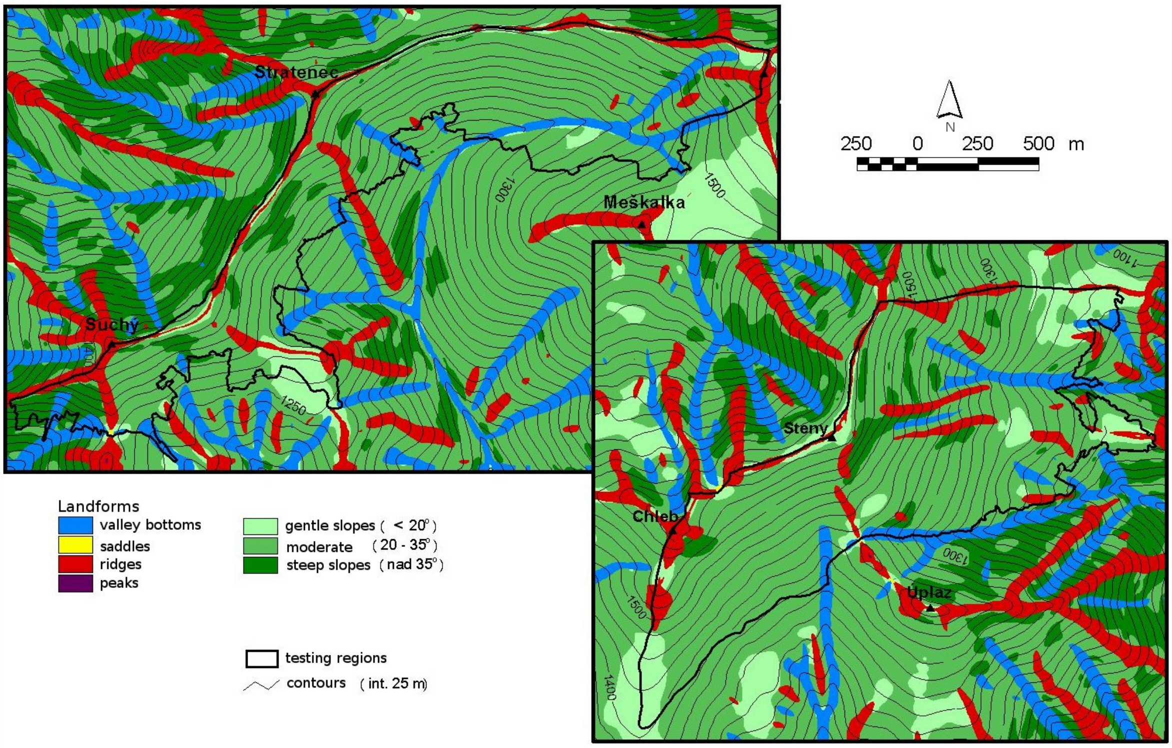

Fig. 5. Landforms.

The changes in distribution of disturbed areas. The changes in the distribution of areas with disturbed soil and vegetation were evaluated on two slopes within testing regions. The first evaluated slope lies on the south-east side of Biele skaly Mt., the second is situated in the upper part of steep and wide valley called Predný žľab (Fig. 2). The morphometric conditions of the slopes are very similar but one of them (Biele skaly Mt.) has not been grazed for about 30 years while the second one was grazed until the summer of 2000. The mean inclination of the slopes is 31-32°, elevation varies between 1220-1610 m with east and south-east exposition. Only small parts (< 10%) of the evaluated slopes are covered by dwarf pine. The area and percentage of disturbance classes on the evaluated slopes and their changes in 2002(2003), comparing to 1992, are given in Tab. 2, 3 and 4.

Table 2. The area and percentage of disturbance classes (SE slope of Biele skaly Mt.).

	1992		2002	
Vegetation and soil covers	Area [m2]	Percentage	Area [m2]	Percentage
1 Undisturbed	88 357.50	96.11	90 895.25	98.87
2 Disturbed	3 128.50	3.40	884.00	0.96
3 Destroyed	444.25	0.48	151.00	0.16

Table 3. The area and percentage of disturbance classes (SE slope of Predný žľab valley).

	1992		2003	
Vegetation and soil covers	Area [m2]	Percentage	Area [m2]	Percentage
1 Undisturbed	114 094.50	63.85	132 579.75	74.20
2 Disturbed	57 742.75	32.32	44 644.00	24.99
3 Destroyed	6 842.50	3.83	1 456.00	0.81

Table 4. The changes in disturbance of soil and vegetation covers

Class		Predný žľab valley		Biele skaly Mt.	
1992	2002-3	Area [m2]	Percentage of the same class area in 1992	Area [m2]	Percentage of the same class area in 1992
1	1	102 857.50	90.15	88 037.75	99.64
	2	10 548.75	9.25	317.50	0.36
	3	688.25	0.60	2.25	0.00030
2	1	28 433.00	49.24	2 716.50	86.83
	2	28 916.00	50.08	359.25	11.48
	3	393.75	0.68	52.75	1.69
3	1	1 289.25	18.84	141.00	31.74
	2	5 179.25	75.69	207.25	46.65
	3	374.00	5.47	96.00	21.61

Both evaluated slopes show increase of the area of undisturbed class in evaluated period. The disturbance and its change on the slope of the Biele skaly Mt. were very small. One third of the destroyed class (in 1992) was completely recovered by vegetation and one half at least partially. Disturbances on this slope are caused by avalanche activity and are usually local. After several years from initiation, if no other big avalanche occurs, they are gradually recovered by new vegetation. However, decrease in count of plant species is significant on recovered places. Thickness of the soil profile is smaller and the stoniness in the upper part of profile is higher. The Predný žľab valley was far more disturbed in 1992 (Fig. 6). Undisturbed vegetation covered only 2/3 of the slope in 1992, but almost ¾ in 2003. The end of grazing in 2000 led to the improvement of the vegetation cover. New destroyed places were created by avalanches as the half of the destroyed area is situated on the undisturbed class of 1992. Disturbance can be seen on the same places on aerial photographs in 1949, but not in 1992. It means that disturbance by avalanches appears on this slope in the cycle of decades. Differences between two evaluated slopes were caused by grazing. Cattle paths in Predný žľab valley were eroded by runoff and avalanches, they gradually joined and only small remnants of vegetation were left especially around the watering places. Avalanche activity occurred on both slopes.

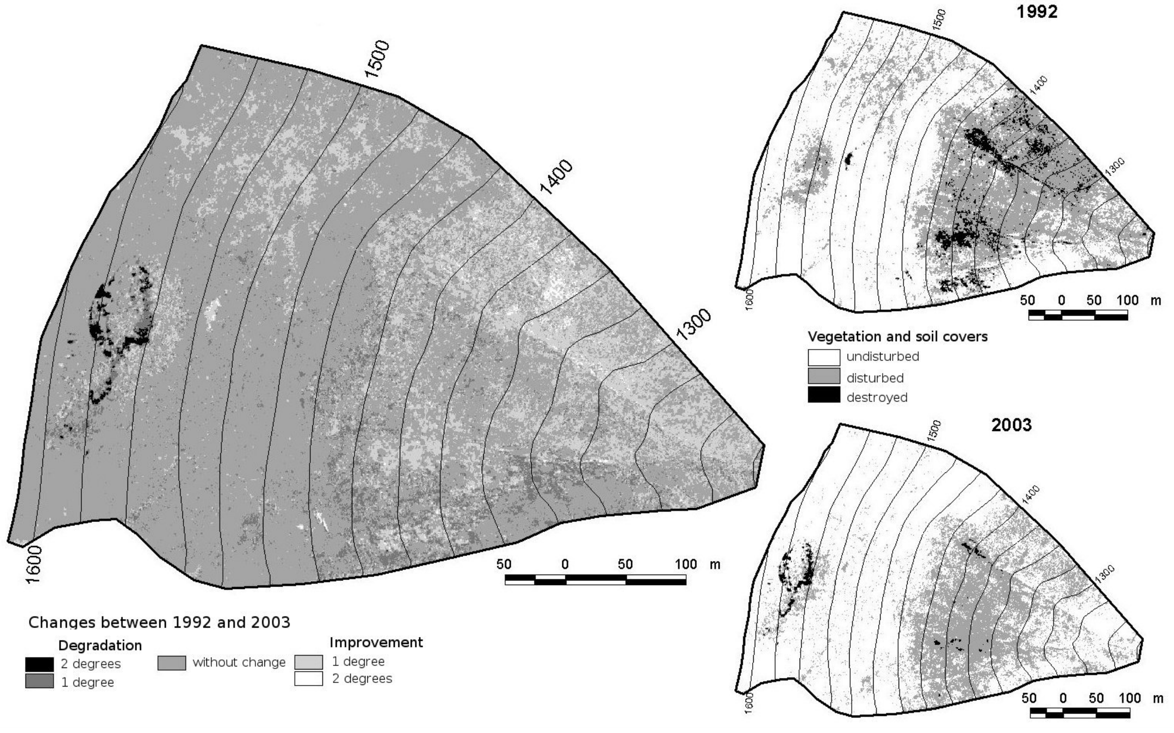

Fig. 6. The changes in ditribution of disturbed areas.

Morphodynamic systems. The prevailing systems in testing regions are those with runoff as a dominant geomorphologic process. They cover 2/3 of the testing regions. One third of the testing regions was classified as systems with dominance of avalanche activity. Gravitational systems occur only in the first region. The systems with other dominant processes cover only a few square meters. The linear systems were evaluated by density (in km/km^2). The density of anthropogenic systems is higher in the first region, but their influence is higher in the second one due to more intensive recreational exploitation.

Table 5. Morphodynamic systems in testing regions, percentage of the area of testing regions or density of linear systems. Enquiry character (?) means that area was not mappable (probably only several square meters).

Morphodynamic system	Character of the system	Percentage [%] or density		
		Region 1	Region 2	Total
RUNOFF SYSTEMS	*Systems with dominant runoff processes*	*72.18*	*61.20*	*66.47*
runoff	Almost inactive slope with undisturbed vegetation	21.00	17.94	19.41
avalanche-runoff	Grassy slope with occurrence of avalanches without strong influence	23.55	-	11.28
gravitational-runoff	Slope with inactive landslide, covered by grass or dwarf-pine	9.14	22.59	16.14
gravitational-avalanche-runoff	Grassy slope with inactive landslide, with occurrence of avalanches without strong influence	4.78	12.73	8.92
fluvial-runoff	A concave slope or wide valley bottom with springs or small water streams	2.16	0.39	1.24
aeolian-runoff	Wide ridge with disturbed vegetation	5.46	4.63	5.03
nivation-runoff	Mostly grassy slope with occurrence of nivation landforms where snow fields act	?	?	?
anthropogenic-runoff	Places with artificially disturbed vegetation	?	?	?
avalanche-fluvial-runoff	Steep chutes with ephemeral water streams and occurrence of avalanches without strong influence	2.76	0.10	1.38
avalanche-aeolian-runoff	Wide ridge with disturbed vegetation and peripheral influence of avalanches	0.30	0.60	0.46
gravitational-fluvial-runoff	Valley bottom on stabilized landslide with ephemeral water stream	0.06	0.68	0.39
gravitational-aeolian-runoff	Ridge on stabilized landslide with disturbed vegetation	2.78	-	1.33
gravitational-avalanche-fluvial-runoff	Bottom valley on stabilized landslide with ephemeral water stream and occurrence of avalanches without strong influence	0.19	1.37	0.80
gravitational-avalanche-aeolian-runoff	Ridge on stabilized landslide with disturbed vegetation and peripheral influence of avalanches	-	0.17	0.09
FLUVIAL SYSTEMS	*Systems with dominant fluvial processes*			
fluvial	Stream channel and its banks	1.51 km/km^2	0.69 km/km^2	1.08 km/km^2
gravitational-fluvial	Stream chute with intensive lateral erosion	?	?	?
AVALANCHE	*Systems with dominant avalanche activity*	*27.68*	*38.77*	*33.45*

SYSTEMS				
runoff-avalanche	Slope with intensive disturbance by avalanches	23.89	27.16	25.59
fluvial-runoff-avalanche	Steep chutes and valleys with ephemeral water streams and intensive disturbance by avalanches	2.60	1.98	2.28
gravitational-runoff-avalanche	Grassy slope with stabilized landslide and intensive disturbance by avalanches	0.34	4.45	2.48
aeolian-runoff-avalanche	Steep ridge with disturbed vegetation and intensive disturbance by avalanches	0.69	3.66	2.23
gravitational-fluvial-runoff-avalanche	Valley bottom on stabilized landslide with ephemeral stream and intensive disturbance by avalanches	0.04	1.11	0.60
gravitational-aeolian-runoff-avalanche	Steep ridge on stabilized landslide with disturbed vegetation and intensive avalanche activity	0.12	0.41	0.27
GRAVITATIONAL SYSTEMS	*Systems with dominant gravitational processes*	*0.10*	-	*0.04*
runoff-gravitational	Slope with creeping debris and remnants of vegetation cover	0.06	-	0.02
fluvial-runoff-gravitational	chute with creeping debris, remnants of vegetation and ephemeral water stream	0.04	-	0.02
AEOLIAN SYSTEMS	*Systems with dominant aeolian processes*	*0.04*	*0.03*	*0.04*
aeolian	Peak or saddle with disturbed vegetation	0.04	0.03	0.04
ANTHROPOGENIC SYSTEMS	*Systems with dominant anthropogenic processes*			
anthropogenic	Surface of the hiking trail	5.45 km/km^2	4.32 km/km^2	4.86 km/km^2

4 Discussion

Comparison of soil erosion maps and field research showed that the maps of destructiveness and potential erosion gave relatively higher erosion values than the actual erosion is observed. Map of destructiveness classified almost the whole area as a very susceptible to soil erosion. The map of potential soil erosion also looks very similar. High erosion values results from the high accent given to slope factor during evaluation. Computation of soil erosion and deposition, based on USPED model, led to considerable different results. Although the computed values are only relative, the most of the area was classified with values close to zero. The difference could be explained by complexity of the model equation and exclusion of vegetation. The models of soil destructiveness and Frevert-Zdražil's equation do not take into account the upslope contributing area or even slope lengths, so these models are dependent on slope steepness only (only one topographic factor). The USPED model on the other hand takes into account upslope contributing area which approximates the actual runoff. However the field research showed that the soil was not completely removed even if it was not covered by vegetation and situated on steep slopes. All three maps proposed very high erosion in such localities, leading to removal of the soil within several years. None of the evaluation procedures includes stoniness and the protection of the stone and gravel pavement; it could be a subject of the future research and modeling of soil erosion in alpine environment.

5 Conclusions

Runoff processes and avalanche activity are the dominant geomorphologic processes within alpine environment of the Malá Fatra Mts. A wide range of other processes act in these area, although with much lower intensity. Various natural conditions of Malá Fatra Mountains offer good opportunity to verification of different models of geomorphic processes. A confrontation of soil erosion maps with erosion observed in reality led to conclusion that in this type of environment the stoniness of the soil is the factor which should be included to evaluation to developed more accurate models. Remote sensing techniques are useful in the process of evaluation of distribution of disturbed soil and vegetation covers. They could be used also in process of verification during morphodynamic modeling. Resulting map of morphodynamic systems is usable for management of protected area.

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