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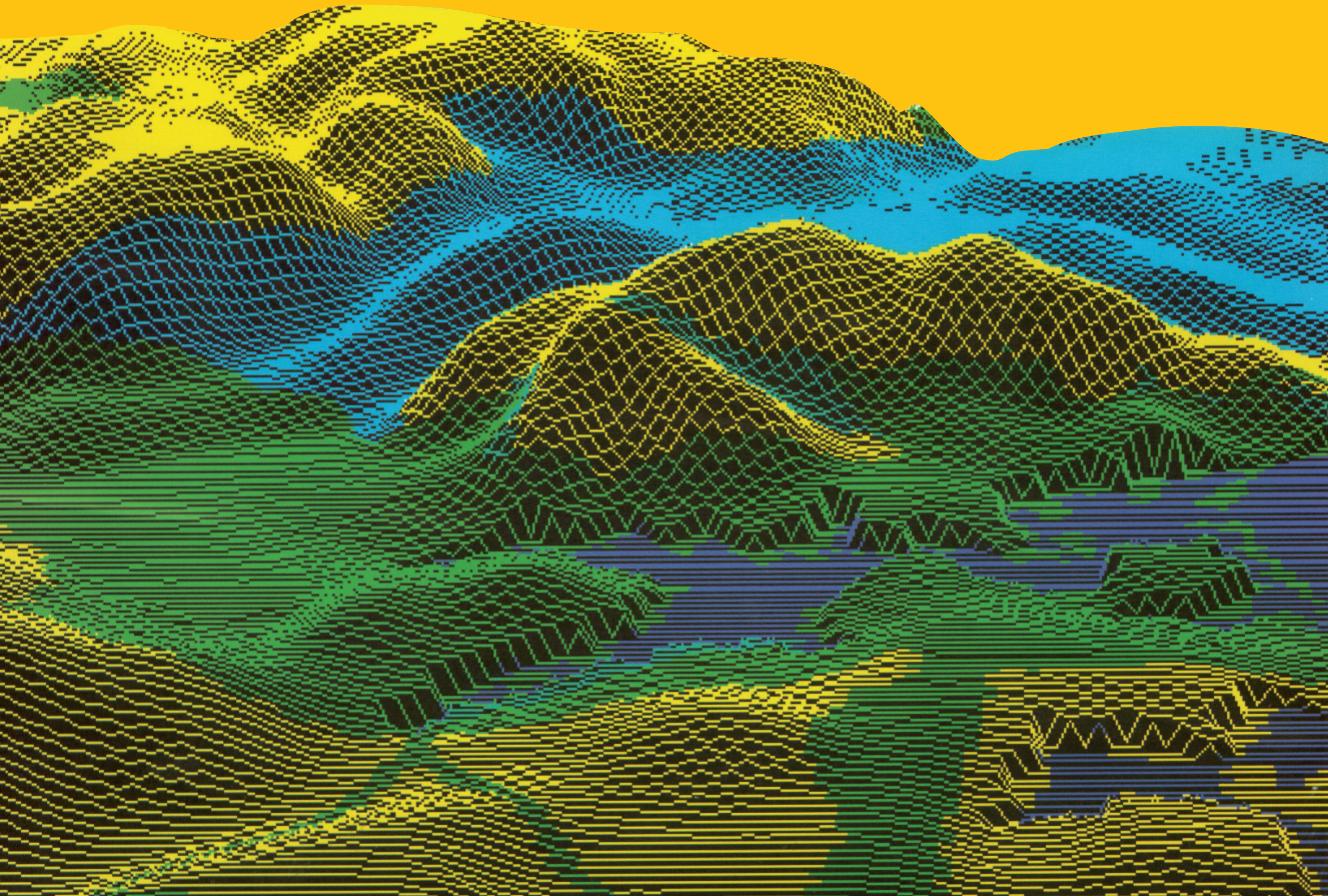

Fig. 9: Productional and cultural landscape in the region of Moravská Třebová. Diverse conditions of the primary structure and human interests according to the tertiary structure led to the development of the secondary structure – a mosaic of settlements, grasslands, fields and forests, usually integrated in local economy with hand-made, industrial, agricultural and forest production (Photo J. Kolejka)

Fig. 10: Agglomeration of the industrial town of Blansko and adjacent villages intensively consolidates along the electrified railway, regulated waterway and local roads through the construction of industrial, commercial and warehousing premises, avoiding abandoned sites after mining of shales and construction sands, which partly became brownfields and partly were left to natural succession or to non-organized motor sport (Photo J. Kolejka)

Illustrations related to the paper by J. Kolejka and P. Trnka

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ASSESSMENT OF LANDSCAPE CHANGES: THEORETICAL STARTING POINTS FOR STUDY AND THE RESEARCH REALITY

Jaromír KOLEJKA, Pavel TRNKA

Abstract

The definition of identification criteria, evaluation and prediction of landscape changes follows out from key parameters of the individual landscape structures (natural – primary, functional = economic – secondary, human = social – tertiary, potentially spiritual – quaternary = genius loci) of the characterizing invariants. Periodical recurrence of processes maintains the structures of the landscape within its spatial, functional and temporal aspects but it concurrently leads to a gradual transformation of one landscape into another. The landscape form is therefore subject to alterations as well. In the CR the study of landscape changes is confronted with the problem of a limited field surveying as opposed to laboratory data processing concerning the land use in different periods (statistical data, old topographical maps, remote sensing data). Long-term measurements are missing namely in the primary landscape structure. A complex study of landscape is thus feasible only within the scope of geography disposing of data and knowledge concerning all landscape structures together with their aspects and changes. It would be optimal if a complex geographical station were established to enable extended measurements and observations of the landscape with emphasis on changes in the spatial aspect.

Shrnutí

Hodnocení změn krajiny: teoretická východska studia a výzkumná realita

Stanovení kritérií identifikace, hodnocení a prognózování změn krajiny vychází z klíčových parametrů jednotlivých struktur krajiny (přírodní - primární, funkční = ekonomická - sekundární, humánní = sociální - terciární, příp. duchovní - kvartérní = genius loci) popisujících invariant. Periodické opakování procesů udržuje krajinné struktury, a to v jejích prostorových, funkcionálních a časových aspektech, ovšem současně vede k postupné změně jedné krajiny v druhou. Tím se mění i vzhled krajiny. V ČR se studium změn krajiny potýká s problémem omezeného terénního průzkumu ve prospěch laboratorních zpracování dat o využití krajiny v různých obdobích (statistická data, staré topografické mapy, data DPZ). Chybí dlouhodobá měření zejména v primární struktuře krajiny. Komplexní studium krajiny je tak realizovatelné jen v rámci geografie pokrývající daty a poznatky všechny krajinné struktury, jejich aspekty a změny. Optimálním by bylo zřízení komplexní geografické stanice umožňující dlouhodobá měření a pozorování krajiny s důrazem na změny v prostorovém aspektu.

Key words: *criteria of landscape changes, landscape structures, space-time, dynamics, development, function, invariant, land use.*

1. Assessment of landscape changes – important object of research

1.1 Options and feasibility

Both natural and cultural landscapes are subject to changes. This fact goes hand in hand with the existence of a landscape untouched by humans as well as a landscape multifariously shaped by human activities. The majority of recorded changes evoke various questions (and feelings) that several natural, technical and after all also economic and social sciences try to answer (and explain). With respect to the generally prevailing conservative understanding of all landscape changes as negative phenomena, it is frequently difficult to explicate that such events are a very natural accompaniment of the planet Earth‘s evolution, its nature and human society and that in the majority of cases they cannot be avoided. It should be noted that all local landscape changes form a varied intersection point of processes operating at all scales – i.e. ranging from global, regional and landscape levels to the local scale. Moreover, the stimuli may be in most cases mediated multiple times (indirect impulses), often within a very complex temporal system of causes and consequences.

The study of dynamic landscape characteristics provides a basic synthesized groundwork about the area on which the decisive blocks of a complex geographical prognosis for landscape evolution can be constructed taking into account the needs and activities of the society. Throughout the hitherto evolution of landscape science – or more specifically, geoecology or landscape ecology (for concrete differences in the focus of these disciplines see Fig. 1) numerous research methods for surveying the landscape and its dynamics were elaborated thanks to which a plenty of aspects of the genesis, systemic organization, evolution and functioning of natural and human-impacted territorial entities could be discovered, a fact which has pushed forward the level of knowledge of the Earth's nature and the human environment in general.

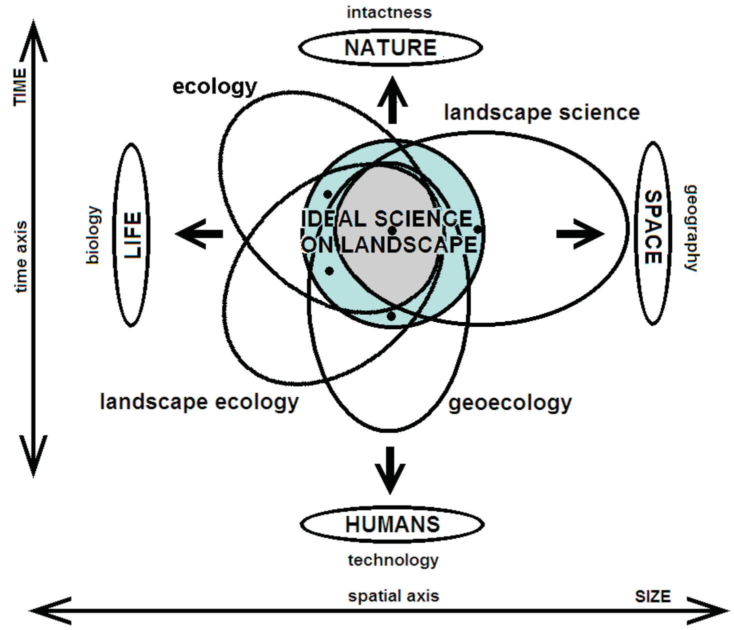


Fig. 1: Distribution of research focuses in the complex disciplines of landscape research

We cannot forget that many other disciplines, regardless of whether they belong to natural, social or technical sciences, consider the landscape as their object of study. Largely they define their object of research (object characteristics) more narowly than geography, landscape ecology or geoecology (e.g. geology, ecology, botany, aesthetics, history, psychology, forestry, agronomy, horticulture, geodesy, cartography, geoinformatics, town planning, landscape planning, politics or warfare). Their findings often provide valuable experience, procedures and facts.

The current stage of studying the landscape's dynamic features, changes and evolution is often characterized by simplifying the knowledge and methodological apparatuses due to the preference of descriptive quantitative aspects of land use by humans (among others also the so-called "landscape metrics"). Of no small significance to this trend, which blossomed also in the CR (but not in Slovakia, France, Italy, Germany, and in the eastern countries) was the American landscape ecology school (e.g. Forman, 2003). The problem is likely to dwell on the fact that diligent field surveying, collection of chronological data series and field landscape mapping were radically abandoned. In the background of this fact is probably the pressure for early publishing of results, limited financial resources for the execution of field surveys and stationary research and undoubtedly also a subjectively reduced mobility of the research staff relying more on previously acquired archived data of all types – from thematic analytical data to spatial data collected by modern technologies such as satellite and aircraft carriers – rather than collecting their own primary data. The research of landscape changes is then grounded predominantly on the assessment of land use changes starting from the oldest suitable historical cartographic records. This essentially inevitably brief trend did not pass unnoticed in the landscape scientist community and hence the first surveys appear which go back to the natural essence of the landscape by searching for synergy between all concerned components and factors of landscape changes and evolution in the form of landscape change indicators.

The "Landscape Ecology" journal issued by the Springer Netherlands publishing house since 1987 has become the forum for the exchange of opinions and experience in the field of landscape study and changes. A study made by Wiens in 1992 and assessing papers published in the journal (see Naveh, Lieberman, 1994) revealed that roughly a half of the (North American) landscape ecologists prefer to study the present landscape mosaic (distribution of functional plots), a slightly smaller segment specialize in land use issues and around one fifth of the experts study plant life. If the landscape dynamic tendencies are at all a subject of interest, the attention is focused on the study of temporal changes in the land use, even less on substances and energy flows and only marginally on disturbances in the landscape system. A recent research (Bastian, Steinhardt, 2002 in Balej, 2005) on the one hand documents an extensive interest on the part of the experts in interdisciplinarity applied to the study of landscape but its practical use is naturally very limited. This is also true about the so-called "ecosystem approach." Landscape metrics continues to be a dominant topic of works published in the "Landscape Ecology" (Bastian, Steinhardt, 2002 in Balej, 2005). There is no doubt that the descriptive and static approaches markedly predominate in the current study of landscape. It is however gratifying to see that the interest in the quantification of problems, computer modelling and simulations (Erwin, Hasbrouck, 2001) has been recently increasing. These methods require groundwork data and final verification and therefore the research of landscape returns at least partly to fieldwork.

1.2 Starting points for the geographical study of landscape changes

Temporal landscape changes as a manifestation of many diverse and often mutually interrelated processes normally require the application of a complex of various research methods. In the selection and use of methods, the following factors play a role: process contents, manifestations, intensity and duration, variability of the processes in space and time, area accessibility, technical, material and personnel possibilities, sense and aim of research (see e.g. Kovář, 2005).

Geography tries to encompass this multilateral diversity by introducing a geosystem principle (Fig. 2) set in space and time. Natural landscape can be considered generally as well as specifically a system of mutually interconnected components the individual role and significance of which vary from place to place. The result of their concurrence is a concrete landscape unit that at a general level has come to be referred to as "geosystem." Another key element – the human component – soil-forming substrate comes into play in the cultural landscape. Similarly to the other natural components, the human geosystemic contribution to the landscape genesis and functioning is manifold. Geosystem is a functional and dynamic unit of space, location, georelief and all natural and man-made material elements of the geographical sphere – of the geological bedrock, soil-forming substrate, waters, flora and fauna, human creations and products, their attributes and reciprocal relations (Miklós, Izakovičová, 1997).

Landscape ecology takes the landscape for a heterogeneous part of the Earth's surface consisting of a set of interacting ecosystems rerring in similar forms in a given part of the surface (Forman, Godron, 1993). Ecosystem (Tansley, 1935) is a set of organisms and factors of their environment in the unity of any hierarchical level. The attention is focused particularly on the functioning of these units.

We can also mention anthropocentric approach to the study of landscape in which the research of landscape expediency for humans (ranging from usefulness to risks) lies in the centre of attention.

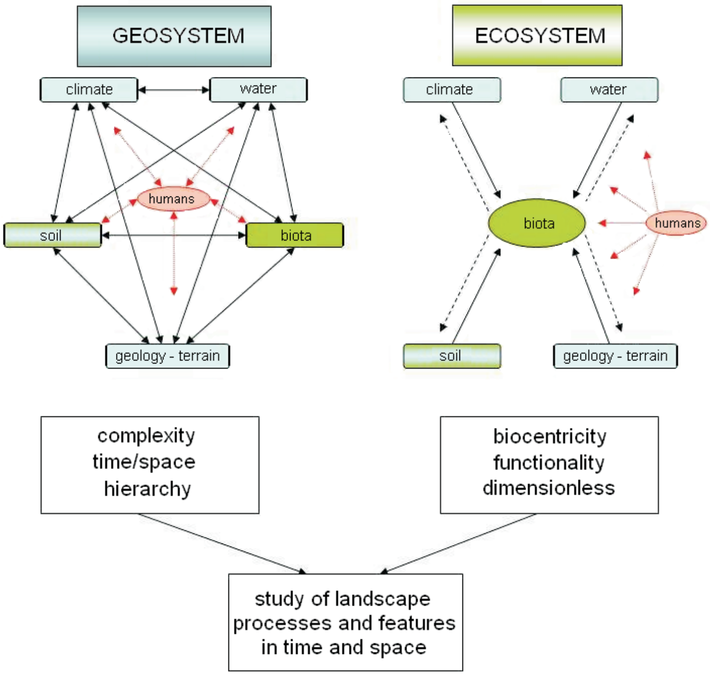


Fig. 2: Variations of preferences in the study of landscape in geography (landscape science – geosystemic approach) and in ecological sciences (landscape ecology – ecosystemic approach)

1.3 Spatial levels of landscape research

The application of a four-grade territorial scale used for differentiation and landscape study is grounded on the concept of a determinative and controlling role of energy available in a landscape system (Fig. 3). At a global level – in the Earth‘s landscape sphere – landscape (climatic, energetic) zones (from equatorial to polar) originate on the basis of the primary distribution of direct solar radiation thanks to the astronomic parameters of the Earth's shape and movement. Energy redistribution, represented by additional doses of energy or by energy shift-offs backed by planetary air and water circulation, runs on the regional level where the landscape zones or geoms are profiting from primary water distribution between land and sea. The landscape (choric) level (Fig. 4) is characterized by the tertiary redistribution of solar energy through the aspect of slopes to solar radiation, secondary redistribution of moisture through the orientation of the windward and leeward slopes to the incoming moisture and evaporation, and primary redistribution of the solid matter in the removal, transit and accumulation landscape segments. At the local (topical) level, the final (geographic, territorial) redistribution of energy (accumulation versus expenditure), moisture (creation and withdrawal of reserves) and solid matter (sedimentation, denudation, erosion, transport) takes place in line with the seasonal dynamics of landscape formation processes in local homogeneous geosystems – geotopes (uniform natural background and usually a unified human utilization). While geography at a local level primarily investigates the horizontal transfer of flows and exchanges of energy as well as solid and liquid matters (potentially also of information), other natural disciplines predominantly concentrate on the vertical transfer of flows and their results. The individual geographical disciplines consequently present an important source of data and knowledge for the respective levels (climate geography – ranging from global to choric, hydrogeography – regional to local, geomorphology – regional to local, soil geography and biogeography ranging from choric to local – largely by means of evaluating, generalizing and defining the indicators of flows and changes). There is doubt that the individual geographical disciplines dwell on “auxiliary” (for geography) disciplines (climatology and meteorology, geology, pedology, botany, zoology and ecology. The different scale for the application of indicators is known since long time ago (Zonneveld, 1995).

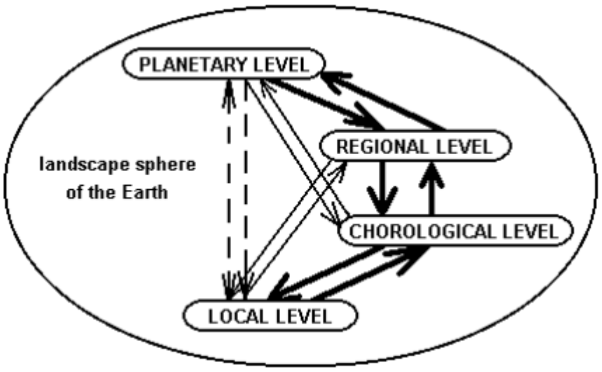
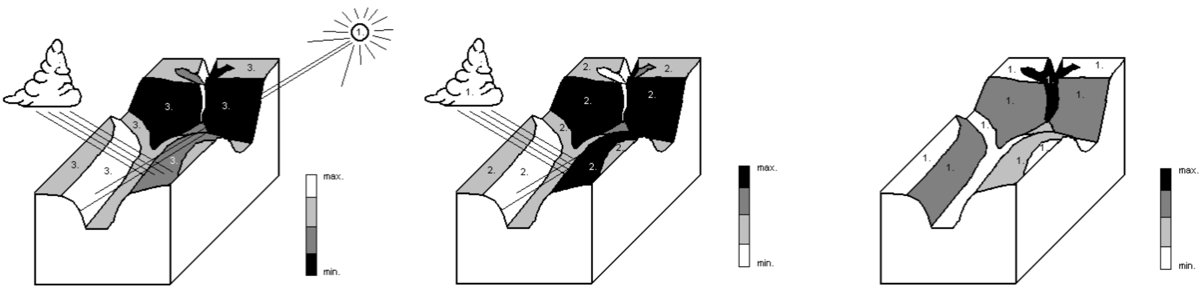


Fig. 3: Landscape differentiation scales and levels of landscape changes research (showing the intensity of links between the individual levels)

One needs to be aware that landscape changes at a local level directly reflect in the transformations at a choric (landscape) level. The connection to global manifestations of local changes is difficult to prove but its existence is beyond any doubt. In a similar fashion, the impacts of global changes are hardly provable, yet they need to be taken into account. It is therefore necessary to bear in mind already at a stage of formulating the concrete project methodology for studying the landscape changes at which level of landscape differentiation the research is going to be conducted (Sklenička, 2003).

1.4 Landscape and time

Several authors tried to determine the time scale for geographical phenomena. These attempts gave rise to a series of period classifications, which either represent periods of recurrent changes, periods of developmental transformations or, more precisely, the length of their duration (Purdik, 1979; Fedina, 1982; Beruchashvili, 1983; Mamaj, 1982; Forman, Godron, 1993; Farina, 2006 etc.).



primary (direct and indirect solar radiation), secondary (air masses) and tertiary (by slope and aspect) territorial distribution of warm

primary (air masses) and secondary (by slope and aspect) territorial distribution of water

primary (by slope) territorial distribution of solid matter

Fig. 4: Redistribution of energy, moisture and solid matter leads to the formation, maintenance and transformation of landscape

In the case of recurrent changes, these are mainly the conditions of landscape the repetition of which is an essential prerequisite for the preservation of landscapes – natural as well as cultural. The conditions are divided into three main groups (Beruchashvili, 1983):

1. short-term conditions – time of duration shorter than 24 hours,
2. medium-term conditions – time of duration between 24 hours and 1 year,
3. long-term conditions – duration over 1 year.

For comparison, it is possible to mention the example of quantified scale terminology used in hydrological modelling (Dooge, in Blöschl, Sivapalan, 1995):

Spatial scale:

identification	dimension
local	n.1 m
hillslope	n.10^2 m
catchment	n.10^4 m
regional	n.10^6 m

Time scale:

identification	dimension
event	days
seasonal	years
long-term	centuries

Because the duration of changes is temporally unlimited in the case of permanent changes, i.e. developmental transformations, we can consider only the classification of the onset duration of a concrete change. In such a case, the occurred change is a product of a single event of a short-term (e.g. disastrous) character (in seconds, hours, days and months), an event of a medium-term duration (colonization, succession, construction etc. – ranging between one year and one decade), or a long-range process (climate change, exchange of civilizations or a change of a socio-economic and political systems – measured in decades and even centuries).

The question remains what can be considered a "zero" condition, i.e. the starting point from which the research of temporal changes of the landscape, its evolution and dynamics should begin. The minimum requirement is a conventional determination of the definition core of each landscape and a time horizon from which the self-preservation recurrent conditions or phased developmental tendencies towards another landscape unroll.

2. Key landscape characteristics

The Siberian landscape school developed the term "invariant" for the purpose of defining a "stable" set of landscape characteristics. They use the term to describe the definition core (and its key characteristics) of each landscape unit – geosystem (Sochava, 1978; Krauklis, 1973). Geosystem properties are a manifestation of the concrete form of an integrated effect of landscape-forming factors. Structure stands for the elementary differential property of geosystems. It is also the essence of an invariant in its role of a complex definition feature of each geosystem. The invariant is a set of geosystem model characteristics. The actual structure is defined by the character of the unity of all structural elements and components that form the concrete system as a result of mutual relations and in compliance with external and internal conditions of its existence. We can distinguish the spatial, functional and temporal sides of structure. The structure of geosystems is subject to changes in space and time accompanied by the formation of new geosystems in an incessant evolution of nature and human society.

With respect to the spatial and temporal manifestations we can distinguish three aspects of landscape structure (Krauklis, 1973; Beruchashvili, 1983):

1. Spatial aspect (**spatial structure**) – taking into account the mutual position, interconnection and directions of the links of structural parts within the framework of a single landscape unit between its structural components as well as between the individual landscape units. This spatial vertical structure thus demonstrates the spatial arrangement of the landscape structural components (Fig. 5) or – as a horizontal structure – it shows the territorial distribution of landscape units of a lower order within the framework of higher-order units (Fig. 6).

2. Functional aspect (**functional structure**) – relates to the mechanism of the landscape's system functioning. It depends on the arrangement and roles of landscape structural blocks. Some landscape units present a source of energy or material for other units, some landscape units are able to accumulate material and energy, while other units play the role of a trigger for specific processes, etc. (Fig. 7). Their purpose is on the one hand preservation of the landscape system either by means of its internal adaptation to altered external conditions or by a protection or creation of a "filter" weakening external factors, potentially also transforming the external influence into a "less harmful" form. On the other hand, these processes are nothing else but a complex of gradual adaptation to external conditions which, if they are of "permanent" nature, condition the change of the invariant and the formation of a new landscape through evolution.

3. Temporal aspect (**time structure – chronological structure**) – follows out from the chronological changes of structural parameters within the scope of self-regulating "life cycles" of geosystems without any deformation of the invariant. In other words – the time structure is based on a typical sequence of characteristic conditions of a landscape unit.

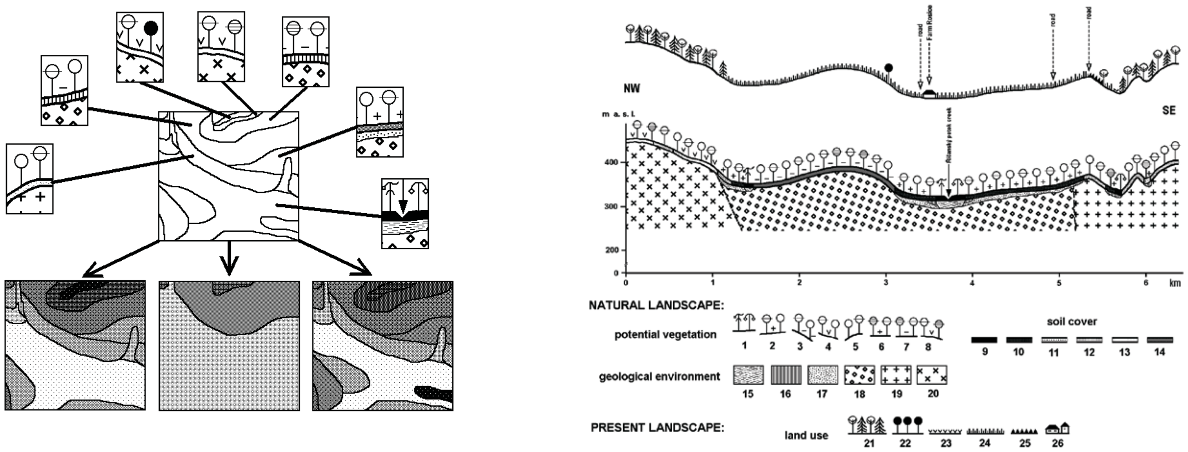


Fig. 5: The concept of vertical structure of natural landscape as an interconnection of structural landscape components in the form of sections through individual types of homogeneous landscape units (on the left) or in the landscape profile illustrating the interconnection of vertical structures into the resulting horizontal structure (on the right)

Legend: **Potential vegetation cover**: 1 – Ash-Alder, 2 – nutrient-rich Beech-Oak, 3 – drought-prone Beech-Oak, 4 – acidic Beech-Oak, 5 – fresh Beech-Oak, 6 – loamy Oak-Beech, 7 – drought-prone Oak-Beech, 8 – acidic Oak-Beech; **Soil cover**: 9 – haplic gleysol, 10 – gleyic fluvisol, 11 – luvic chernozem, 12 – haplic luvisol, 13 – haplic cambisol, 14 – calcic cambisol; **Deposits**: 15 – alluvial sandy loams, 16 – slope deposits, 17 – loess; **Solid geological bedrock**: 18 – calcareous conglomerates and sandstones, 19 – granitoids, 20 – gneiss; **Current land use**: 21 – cultivated forests, 22 – fruit orchards, 23 – cultivated meadows, 24 – field crops, 25 – built-up area

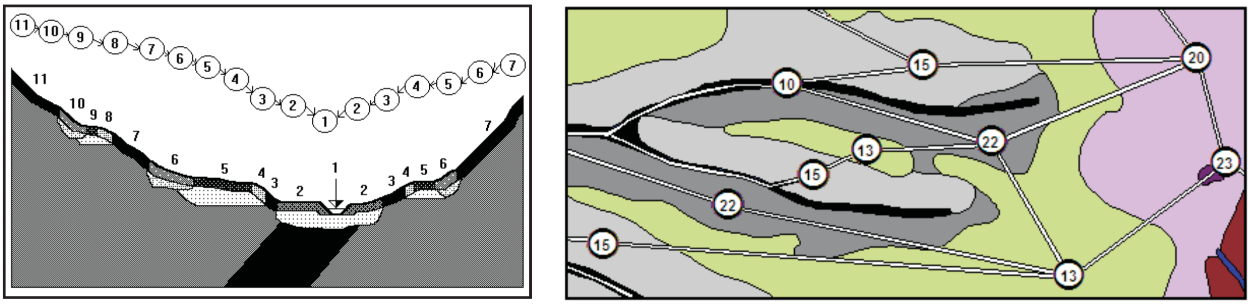


Fig. 6: Horizontal spatial structure of landscape as a catena of geotops (left) or as a system of interlinked partial units of a choric level (right)

Based on archaeological and historical data, a reconstruction of the past landscape conditions can be carried out for the crucial period of the past, the present (current) condition of the landscape can be critically assessed and attempts at forecasting the future landscape development can be made.

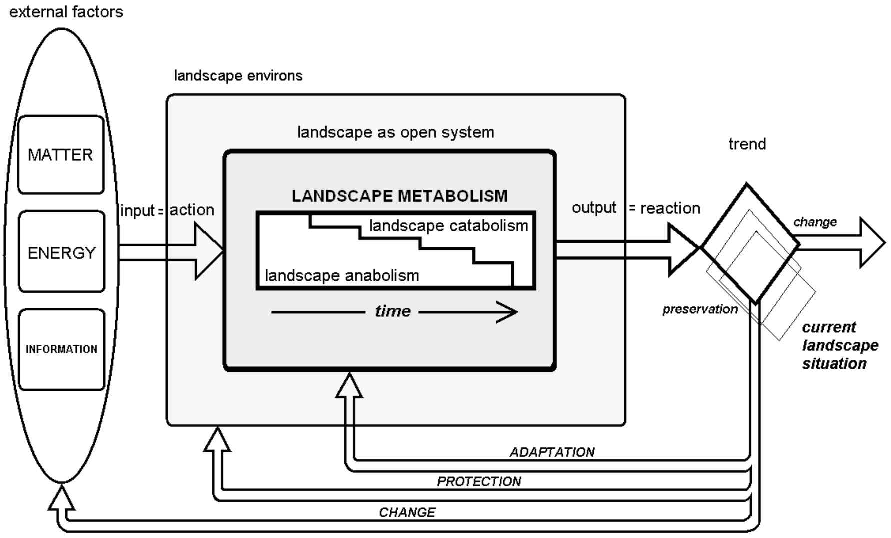


Fig. 7: Diagram of the procedures of landscape response to external stimuli and to the need for internal balance

With respect to the differentiated roles in the current landscape, a genetic succession of structures can be distinguished (according to Haase 1964; Neef 1967; Isachenko, 1965; Ružička, Ružičková 1973; Armand, 1975; Milkov, 1978; Drgoňa, 1983; Richling, 1985; Zonneveld, 1995; Miklós, Izakovičová, 1997; Hrnčiarová, 2004; Turner, 1996 etc.) as follows:

1. *Natural (primary) structure* – formed as a result of the activity of natural factors and processes and consisting of a system of synergically interconnected components (water, air, weak and hard rocks and earths, terrain, energy, soil and biota) and partial territorial units with regular conditions in space and time. The individual parts thereof can undergo transformations due to human impact.

2. *Land use (secondary) structure* – representing the human-made superstructure formed by a mosaic of land use forms the substance of which is evidenced by spatially arranged areas of forests, arable soil, meadows and pasture lands, built-up areas of various purposes, permanent crops and many others but always of a differentiated quality (e.g. according to the degree of ecological stability, naturalness or transformation, balance etc.), exploitation intensity and scope (Kolejka, 1982).

3. *Human (tertiary) structure* – represented by diverse social and individual interests located in space, limits and developmental motives, but also demographic and social parameters of the territory. The interests that lie "below" different socio-political motivations or traditions range from multifarious protective measures to legislative, technological, environmental or ownership limitations.

4. *Spiritual (quaternary) structure* – which can be understood as a symbolical spatial pattern, emotionally perceived as "genius loci" of the landscape grounded on imaginary as well as real events (battlefields, sojourns of famous personalities, legends, fairy tales etc.).

3. Landscape in change

Both natural and cultural landscapes are subject to incessant cyclic and eventually irreversible transformations depending on from where and what kind of impulses they receive. While cyclic changes lead to landscape invariant consolidation, irreversible changes bring about invariant transformation and therefore cause the evolution of another landscape. Establishment of invariant values for a specific landscape depends on available data. While the primary structure invariant can be derived from the determination of vertical and horizontal potential natural landscapes based on the current data, the invariant for secondary and tertiary structures should be based on the oldest reliable data on land use and spatial distribution of interests (limits). This approach can be logically attacked as it is characterized by internal dichotomy and temporal inconsistency. The initial structure is defined in the present while the second one is defined in the as remote as possible past. It can be namely assumed that the initial secondary structure has evolved within a primary structure different from the existing one. On the other hand, the primary structure can be hardly reconstructed for the period to which the first information about the secondary and tertiary structures relate on the grounds of the present records. Similarly, the current condition of the secondary structure cannot be considered as initial and its previous forms in the past cannot be derived from it because the developmental and transformation time line proceeded in a reverse direction. The definition of invariants is thus only conventional and is given by all available records (esp. those concerning the individual structures in a chronological order).

Viewed from a general perspective, the landscape dynamics (e.g. the variability of landscape parameters during the day and year but not of the invariant over time) is internally contradictory (Sochava, 1978). Although it stabilizes and maintains the landscape, it is eventually also the cause for its transformation – i.e. evolution into a different landscape. From the developmental perspective, the replacement of invariants by other ones is identical to the evolutionary process of the Earth's landscape sphere regardless of whether the transformation occurred either due to external (background) factors or through self-evolution in the course of geological periods and natural or anthropogenic disasters. Rhythmic processes associated with the daily and annual dosing of energy and moisture can be regarded as the elementary cases of dynamic phenomena. Individual changes to the landscape invariant occurring gradually in all dimensions of the differentiation of the Earth's landscape sphere can be understood as stages in the evolutionary process of nature (and eventually also of the human society) on our planet (Fig. 8).

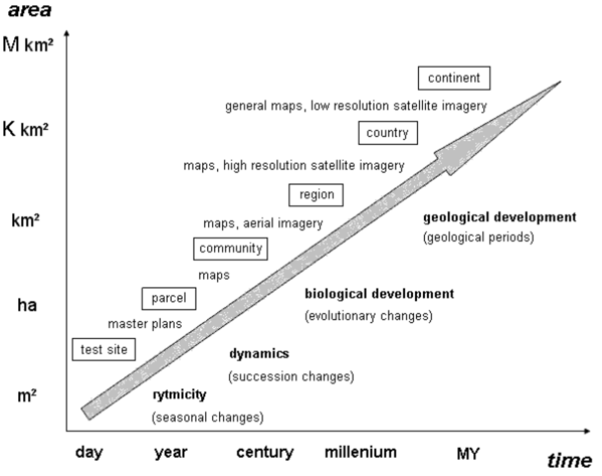


Fig. 8: Relationship between the spatial and temporal dimensions of variable landscape phenomena

Landscape dynamics as an essential definition feature of the landscape is characterized by invariant constancy. The landscape (landscape unit, geosystem) retains identical manifestations over time if its invariant is constant. This constancy nonetheless does not apply in the absolute but only in the relative meaning of the word. The invariant is considered constant only conventionally. In reality, its elements undergo temporary changes during seasonal and other cycles of the processes naturally occurring within the geosystem. Considering the spiral nature of the majority of landscape processes, each cycle moves the landscape towards the interval boundaries (limits of the so-called "normal amplitudes" of rhythms) beyond which the replacement of one invariant by another – and therefore also a qualitative change, in other words, landscape evolution – already takes place.

Landscape evolution is hence characterized by changes to the invariant (consequence of irreversible parameter changes), while landscape dynamics depends on changes to the conditions (consequence of reversible parameter changes).

In spite of the fact that the dynamics conceived as a transformation of landscape conditions under the influence of external and internal forces (Krauklis, 1979) moves the evolution forward, it repeatedly holds it at a similar level in the following cycle. Therein its internal contradiction consists. Dynamic (or better expressed - cyclically occurring) conditions in this sense stabilize the landscape unit and implicate the renewal of fundamental or nearly fundamental state. The stabilizing role of dynamic phenomena is realized only if the individual processes mutually compensate each other and create conditions of a dynamic balance; these two factors demonstrate the system‘s stability. The above stated principles assure the landscape‘s duration and its functioning. The incessant adaptation of biota activities and mobile components to the changing external conditions (primarily energetic) nonetheless leads to the evolution of landscape skeleton (namely relief and mantle rock) and to the gradual evolution shift of landscape unit within the framework of one invariant. If the stability threshold is exceeded, the invariant changes and the concrete landscape unit becomes transformed into another one (considered that significant changes to the background or intensity of self-evolution results occur). Antigonic action of self-preserving and transforming processes is typical also for the modern landscape (Fig. 9). Typical processes maintain the rural agricultural landscape, other ones sustain the urban, industrial, recreational etc. landscapes. It must be however also taken into consideration that a close relation exists between the landscape dynamics parameters and the scale, i.e. measure of the differentiation of the monitored processes (Farina, 1998).

The source of landscape dynamics is therefore seen in relations between the landscape components (response of one component to the parameter change of another one) and external factors represented by regular doses of available energy (in daily and annual cycles), or potentially by moisture doses (depending on the period of precipitation either in solid or liquid form, inundations, droughts) and the supply of solid material (weathering, soil erosion and sedimentation). Conversely, the *source of landscape evolution* is chiefly seen in external factors

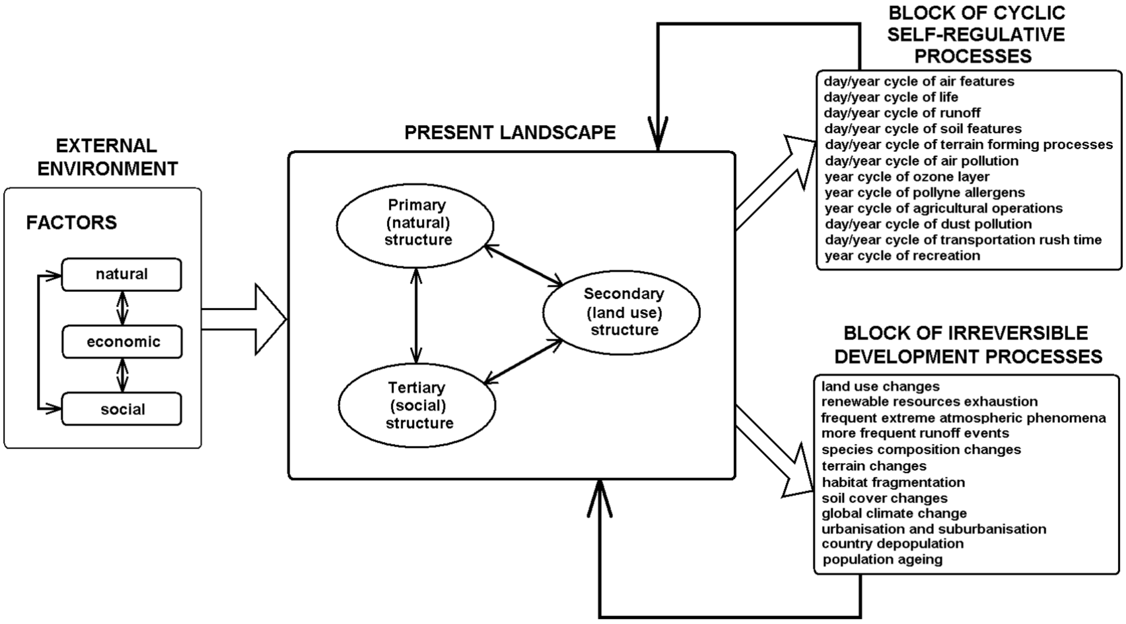


Fig. 9: Structures of the modern landscape and their maintenance through self-preserving processes (only examples listed in the figure) and their change under the influence of irreversible processes (only examples) initiated by factors of external environment (the landscape‘s surroundings)

– slow or sudden crossing of invariant limits due to the activity of extraterrestrial (changes in the solar energy doses) and terrestrial (for example orogenic or epeirogenic) processes and also as a result of self-evolution (generally "aging", e.g. of relief – dissection, lowering, planation – or of the biota – origination of new species and societies, extinction of the old ones) and last but not least the human activity. The question is however whether the roughly seven thousand years of human cultural activity is long enough to be referred to as landscape evolution?

Another view of landscape dynamics offers the study of cultural landscape (Lipský, 1995, 2000; Feranec, Oťaheľ, 2001; Bičík, Jeleček, 2003; Olah, 2003) which considers the cyclically occurring (recurrent) processes of human pressure on the landscape (daily, annual: from rush hours to farm work and nature of the recreational activities in the area – Fig. 9) as a decisive symptom of dynamics. Permanent or long-term (final) changes in land use, i.e. in the secondary (functional) landscape structure, cannot be understood as landscape dynamics. On the other hand, such changes are logically accompanied by modifications in the natural subsystem of the landscape – therefore in the natural invariant – provided that such a concrete change evokes such a deep change in the structure. In other words, land use changes represent a change in the secondary landscape structure following a change in the tertiary structure. The change in the tertiary structure, i.e. motives for maintenance or modification of the current activity in the landscape, is locomotion behind the actual change of land use. In the decisive majority of cases, locomotion is represented by material interests referred to as "driving forces." Whether a change will occur of the primary structure depends on the size and duration of such changes.

4. Landscape succession in time

Selection of the existing primary structure (or of the potential primary structure – which would be formed under existing conditions without human contribution) as a starting point for identification and evaluation of its future changes can be supported by landscape chronological series according to the degree of human transformation.

The line starts with **natural landscape** the structural components and processes of which are not affected by any manifestations of human activity. Although the presence and concentration of people in the pre-agricultural (pre-Neolithic) phase of social evolution undoubtedly brought about changes also to this type of landscape (in the location of settlements and their surroundings, along the trails), these transformations still did not affect the invariant. When the space was abandoned, the landscape returned to the natural state by way of self-regulating processes. Examples of the natural landscape are deserts, polar and subpolar areas, northern and tropical forests, high-mountains, wetlands, steppes in the protected areas and outside them, large national parks. In the territory of the Czech Republic, it is probably represented only by a handful of small areas of glacial cirques walls of limited access in the Krkonoše Mts., Jeseníky Mts. and eventually also in Šumava Mts. (raised bogs).

Near natural landscape already bears more permanent traces of past human presence and activities regardless of their type – agrarian (terraces, canals), mining, urban (settlement terraces, mounds – tells, ruins), celebrative (ground foundations for temples), funeral (graves, burial mounds), communicational (embankments, incisions, narrow-sunken roads) or military (bulwarks, trenches) etc. After the retreat of the human ecumene and succession of natural vegetation, soil cover and other components of the natural landscape became partly regenerated, yet often already on the background of human landscaping artifacts (anthropogenic relief forms). Natural processes are in control of a further landscape evolution. In the Czech Republic, this type of landscape is represented by the unmanaged zones of nature reserves (in National parks, Nature parks and outside them), usually with the forest, meadow and steppe vegetation spontaneously colonizing sites abandoned by humans. The areas of nature reserve and monuments that require human intervention and maintenance (conservation) to preserve the ancient state not corresponding to current conditions (e.g. cutting of the Carpathian herb-rich meadows, liquidation of tree self-seeding in rock steppes, grazing of goats and sheep for the purpose of maintaining the meadow biodiversity), already stand for a transition to the existing types of cultural landscape.

Productive cultural landscape represents an area with the preponderance of the effects of natural processes. People rationally exploit them to produce biomass part of which is withdrawn from the landscape. They conversely return their wastes and substances promoting biomass production. As far as the maintenance of the sustainable development is concerned, it is desirable that the human activity is in harmony with the primary structure above which the secondary structure is constructed (corresponding to the concrete stage of social evolution – the tertiary structure) which selectively respects the area‘s potential. In the Czech territory, this is a typical rural field landscape (in lowland plain regions), forest-field landscape (in highlands), forest-field-meadow landscape (in humid highlands), forest-field-pond landscape (in lowlands and highlands with sufficient moisture), forest-meadow landscape (in uplands and hilly lands) and forest landscape (in marginal areas ranging from plains to hilly lands – Fig. 9 – see cover p. 2).

Regulated cultural landscape – originated due to the dominant human impact on the original natural framework or productive landscape to which people intentionally introduced new processes and structures of high economic efficiency or importance. People nevertheless leave certain space to natural processes but they decide about the location and time of their occurrence. These are for example waterworks and energy reservoirs, irrigated plots, greenhouses, artificially illuminated plots, some recreational sites (golf grounds, grass sportgrounds, sites for extreme climbing sports etc.). Their share is constantly growing together with rising energetic, supply and other needs ensuing from the demographic and social developments (standard of living, leisure time, mobility).

Technical cultural landscape – is characterized by a fundamentally transformed landscape framework as a result of human activity. People introduced new processes and structures into the landscape at respecting the natural phenomena to some degree but these neo-formations are fully controlled by them. Urban, mining and transport landscapes are examples where a series of processes are related to some natural cyclic phenomena (particularly to solar energy doses throughout the day and in the course of the year), but if necessary, the technical means and available "technical" energy make it possible to "ignore" the natural selection of energies (night shifts, lighting, heating etc.). Despite this, exceptional natural phenomena disturbance can affect the sensitive technical infrastructure and alter its function temporarily or permanently (floods, earthquakes, land slides, epidemics etc. – Fig. 10 – see cover p. 2).

The evolution of human society, or ecumene, usually takes place through the transformation of natural landscape into productive one, which turns into controlled and finally technical landscape. Reversals of this evolution are represented by post-agrarian landscape; in extreme cases the regression may lead even to **near-natural landscape**. Abandonment of the originally urbanized or controlled spaces (fortified settlements, castles, oppida, ponds) and their recovery to nature are known also from the territory of the Czech Republic. V. P. Kucherjavij (1999) mentions a continuous chronological series of historical landscapes: Early Medieval, High Medieval, Renaissance, Baroque, Neo-Classical and Industrial. We can only complement it by the Post-Industrial landscape. A reverse evolution characterized by the growing intensity of exploitation is typical for central regions of the country (in the hierarchical system of centres). Marginal regions frequently show retrogressive tendencies, which cannot be equalled with the sustainable development in economic terms but rather with a "forced ecologization" of economically distressed areas.

Natural, near-natural and productive units of the cultivated landscape as open systems show a general prospective tendency towards stabilization (in natural ecosystems aiming towards the climax via seral processes), i.e. towards reaching harmony with the surrounding environment and its factors and also with the internal self-regulating and evolutionary mechanisms. The human impact in a technogenic "cultivated" landscape is nevertheless so extensive that an irreversible transformation of the original natural invariant occurred and in consequence of human activity, a radically new structure was formed. In such an extreme case, the role of invariant is complemented by human activity and by its permanent or maintained product (both technical works and the established way and intensity of land use).

While studying the landscape changes, one needs to be aware that it is necessary to define the original condition, to describe its invariant (with regard to the roles and manifestations of landscapes structures) and to use these data as a comparison basis. This means that for example the identified changes to the secondary structure (the most frequent predictors of change) must be set not only into the topographical framework (identifying the changes in land use) but also in the natural background (type of the environment according to the landscape unit) and socio-political context. In certain cases, framework reconstruction of the initial condition or construction of a potential landscape condition from all structural perspectives can be performed. In the opposite case, the result of "studying landscape changes" is only indirect. As to elementary (topical) landscape units, the deep changes to the structure can appear to be a transition from one invariant to another, while from the perspective of higher taxonomic level units it only stands for a local disturbance.

A starting point to study landscape changes is knowledge acquired through the research of relations between the components of the elementary geosystem, between individual structures of the same landscape unit of natural and modern landscapes. Save for some negligible exceptions (measurement of momentary values of landscape parameters), the study of landscape changes is always diachronic. Diachronic approach cannot be avoided since – with the exception of the measured values necessary to characterize and define the conditions – the description of the condition reflects the result of a comparison with the previous state. Also, the processing of the measured data for the purpose of learning about the processes is conducted with a certain lapse of time or directly "ex-post." A similar situation occurs when classifying the landscape changes according to different perspectives. Besides, diachronicity in the landscape changes is characteristic already for the causes of changes, their onset and arrangement in a time sequence. Every change is a product of previous impulses and usually does not occur immediately but with some lapse of time. It always depends on the landscape structure in which the impulse for change appears first. In the cultural landscape, it is usually the role of the driving forces in the tertiary structure but decisive positions are not excluded in the other structures either (soil erosion, waterlogging, repeated floods in the primary structure and spontaneous changes in the land use in the secondary structure). Every research is therefore synchronous with the processes of landscape changes under way only relatively. J. Kolejka (2007) provides an overview of methods for studying the landscape changes.

5. Study of landscape changes in the Czech Republic

The study of temporal landscape changes is a traditional activity of all landscape schools and it is supported by scientific interest as well as by practical needs. As to the parallel and synchronous existence of the four landscape structure forms, the study should be based on relevant and representative data about each of them. Any decision-making concerning the future of the landscape should in fact take into account its specific characteristics. Landscape structures are closely interconnected even though the primary one plays a decisive role that is relatively least variable in time. Because the CR practically does not dispose of any data collection that would cover the cyclic and irreversible processes in the landscape in a complex manner (especially long-term station observations), an overwhelming majority of surveys dealing with the temporal landscape changes are grounded on diverse assessments of historical data regarding the secondary structure (in short, regarding the past land use). These surveys are based on cartographic data and cadastral statistics encompassing practically the whole territory of the CR in the 19th and 20th centuries; as regards the 18th century and earlier periods, the data quality and coverage decrease rapidly. While until the 1970s these historical landscape surveys were rather rarities due to enormous demands and requirements for manual work, since the gradual introduction of modern computer technology in the late 1970s, the number of such surveys has been growing steadily. Further acceleration of the interest took place after a large number of maps from the military mapping of the territory of the CR deposited in the Vienna Military Archives were made public and after they were digitalized and posted on the web of the University of J. E. Purkyně in Ústí nad Labem (Brůna, Křováková, 2006). Professor B. Veverka from the Czech Technical University in Prague gave yet another impulse by preparing a computer programme georeferencing these data into common cartographic projections used in the CR. Several institutions of the CR responded to the favourable accessibility of historical maps and efficient geoinformation technologies, particularly geographic workplaces at Charles University in Prague by the preparation and elaboration of a series of research projects (Bičík, Jeleček, 2003). The results are miscellaneous historical analyses of land use development or changes from the national to local levels. This trend is in line with the developments in the International Geographical Union (IGU) that has an active working group for Land-Use and Land-Cover Change (LUCC) and also with the elaboration of the environmental history principles (Jeleček, 1995) also under the heading of the IGU.

The level of detail of these surveys varies and it can serve as a basis according to which the information capability of the results of a landscape "changes" analysis can be determined. The evaluation of historical statistical data, mostly for cadastral units, provided a generalized piece of information applicable to comparative operations at a level of a much higher administrative unit (region, but usually the whole CR). This information can be combined with the socio-demographic figures related to the same data-collection unit.

Exact geometric detection of the transition of one form of land use to another one along with the determination of surface area on which the change occurred are among the most frequent cases of landscape-historical surveys in the CR. Such surveys provide information about the replacement of one quality by another with the possibility of considering this process in relation to immutable or transformed areas (built-up area centre, water body, road etc.). Surveys dealing with such landscape changes typically analyse small areas (cadastres or microregions, see Balej, 2007) and result in accurate statistics of the changes.

Setting the change into the environment (characterized by the parameters of natural structure) is a less common case of identification and evaluation of landscape changes. It nonetheless leaves some space for the explication of why these changes occurred, chiefly with regards to the expediency and efficiency of land use (Fig. 7). Other, more suitable forms of utilization gradually replaced areas least suitable for the original purpose.

The additional relating of landscape changes to the tertiary structure can even more likely explain the motives that could have led to the change. In the case of individual cadastral areas, (which is an area size that makes a reliable detailed research of the changes possible) this research has been so far conducted only in the form of a comparison between statistical analyses and not in connection to any concrete areas in a specific territory subject to the given natural conditions.

6. Conclusion

The study of changes continues to be an attractive sphere of geographical research. Although the landscape constitutes a complex object, the realized surveys are often very far from adopting a complex approach. They essentially confine themselves to the identification of changes in land use and their metrics with a sporadic follow up from the primary and tertiary landscape structures. Reliable complex surveys of landscape changes in all of the landscapes structures cannot be conducted due to the lack of field data – chiefly concerning the response of the primary structure to the transformations of other structures. This is fundamentally caused by the absence of a thorough field survey in the form of stationary, semi-stationary or expeditionary studies. The study extensively relies on the available data sources acquired in the past period regardless of their original purposes. This approach is commendable on the one hand because it makes use of the laboriously collected data, but on the other hand, it leads to a certain detachment from the current reality. It can be stated that diverse surveys give strong preference to the recent and historical records concerning the secondary landscape structure, while the pieces of knowledge giving evidence of the primary and tertiary structures are used very rarely and they are practically neither identified, nor recorded. Comparative material is still missing because mapping of the primary landscape structure in many geographical workplaces in the CR is still in its infancy, even though they have declared an inclination towards complex landscape research numerous times. It nevertheless remains within the limits of geostatistics and landscape metrics focusing on the secondary landscape structure parameters.

Compilation of a programme which would combine the virtues of available methods suggests itself for the purpose of a complex study of landscape. It should continue to be based on the following in particular:

1. Precision and regularity of the stationary and laboratory measurements conducted with maximum respect towards the syntopicity and synchronicity principles of information,
2. Measurements of parameters of micro- and meso-spatial substance flows and other chemical and physical parameters of the dynamics,
3. Meso- and macrospatial aspects of landscape states differentiation,
4. Expeditionary inspection of landscape conditions, spatial complementation and corrections of the existing information,
5. Aspect of instant practical utilization,
6. Culturally historical approach.

Stationary and seasonal research works are in fact also struggling with the insufficient interlinkage between their own time series data and the records of culturally historical and socio-economical character that could explain numerous phenomena determined by measuring.

The atmosphere and waters are critical landscape geocomponents. Their characteristics are very dynamic in space and time and they serve as a main transfer medium of energies and substances and form the environment for decisive natural reactions of landscape units with a quasi-invariable location. Wherever possible, the stationary or seasonal research works should positionally and temporally link up with the long-standing series of meteorological, climatic or potentially hydrological observations. With a certain degree of generalization a geographically representative location for a series of follow-up detailed quasi-stationary measurements and observations can be selected from a relatively dense network of such stations. It is highly probable that already the 5-10 year-long series of stationary measurements can be used for comparison with the measurements of the meteorological, climatological or hydrological station network. To a certain degree a time series can be extrapolated from points into space and cover larger areas of interest by a sufficiently reliable piece of information of a dynamic character. In the present period characterized by distinct climatic changes the parallel climatological, hydrological and landscape dynamics measurements are naturally a fairly credible guarantee for sufficient documentation of the evolutionary process in a concrete landscape. Unfortunately, the number of operating geographical long-term field experiment stations globally is very low (the CR does not have any) and they do not representatively cover the area that will be very likely affected by the anticipated environmental changes. If new stationary measurements and observations are conducted, a representative station can be selected in countries with a dense network of stations for the study of aquatic and atmospheric components of the landscape. A follow-up work can be also organized in its environment in line with the best practices from the operation of geographical long-term field experiment stations which would include the spreading of observations over space according to the above stated diagram of study plots in connection to the human activities in the concerned area.

In the conditions of the CR the establishment of a geographical long-term field experiment station assumes a sequence of several operations:

- Selection of a representative location that would respect the existing climatological or meteorological network of stations,
- Execution of detailed landscape mapping in a sufficiently large background of the existing station,
- Localization of points of regular measurements of other parameters of the remaining geocomponents

in a temporal as well as spatial accord with the conducted standard stationary measurements,

- Selection and localization of hierarchically graded plots in the station‘s background of lower frequency, level of detail, scope and smaller set of measurements in a way allowing the study of spatial differentiation of the phenomena and their interrelation in environment of varied human impact (experimental plots, profiles, key plots etc.),
- Definition of periodicity for geocomponent measurements that would be organized in a labour-saving manner with regard to the delayed action and diachronicity of processes; i.e. intervals between individual measurements should be shorter in the case of controlled components and longer for controlling components (apart from standard climatic, ev. hydrological measurements and obser-vations),
- Assurance of the staff (experts), material (instrumentation) and technology (plots, buildings, laboratories, infrastructure) for the geographical station‘s activity and formulation of organizational rules for research works.

At present, the limitation of field research, namely of long-term type, most likely relates to the current state of landscape research funding that lays emphasis on the fast (=short-term) acquisition and publishing of results. It is therefore no wonder that the study of our landscape and its transformations becomes either locally superficial (indirect historical changes in land use) or regionally of rather generalized nature (statistics). Only minor attention is paid to the documentation of the tertiary landscape structure although it is relatively subject to the greatest temporal variability, particularly if we speak about the occurrence of ever more frequent limitations regulating behaviour in the landscape regardless of whether the limits ensue from personal, local, regional or national interests. Support to the social research of landscape requires intense assistance so that, among other things, a real complex geographical conception and interpretation of landscape can be achieved.

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CHANGES IN LAND COVER IN THE AREA OF VYŠNÉ HÁGY – STARÝ SMOKOVEC, IMPACTED BY THE WIND CALAMITY IN NOVEMBER 2004 (SLOVAKIA)

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Abstract

The calamity for forests situated in the Tatras National Park, caused by the whirlwind on 19 November 2004, is distinctive due to the dimensions of the damage. The characteristics of changes in the spatial structure of the land cover in a selected area in the Tatras National Park, in the locality of Vyšné Hágy – Starý Smokovec, are examined in this paper. The research is based on the analysis of landscape structure before and after the wind calamity in November 2004, employing the methodological procedures of CORINE Land Cover. The data and analysis are important for an integrated assessment of the research area and for landscape planning.

Shrnutí

Změny krajinné pokrývky v oblasti Vyšné Hágy – Starý Smokovec postižené větrnou kalamitou v listopadu 2004 (Slovenská republika)

Kalamitní situace v lesích patřících do Tatranského národního parku způsobená větrnou smrští 19. listopadu 2004 byla výrazná svými ničivými rozměry. Cílem práce je charakterizovat změny prostorové struktury krajinné pokrývky vybraného území Tatranského národního parku v oblasti Vyšné Hágy – Starý Smokovec na základě stavu krajinné struktury před větnou kalamitou v listopadu a po ní s vyžitím metodických postupů CORINE Land Cover. Získané informace jsou podkladem pro potřeby integrovaného hodnocení životního prostředí zkoumaného území a pro krajinné plánování.

***Key words**: Land cover changes, CORINE Land Cover, wind calamity, Tatras National Park, Slovak Republic.*

1. Introduction

The calamity situation affecting forests in the Tatras National Park caused by whirlwind on 19 November 2004 is extreme due to the size of damage; however, it is not a solitary event in the last centuries. In forestry praxis, the term ‚calamity' labels an extensive damage of forests disrupting significantly their integrity by whole-area blowdowns, fissures or standing dead trees. The calamity changed the environment of the affected areas with a long-term repercussion. Correct characteristics of the secondary landscape structure (a real state of the surface segment of landscape systems), along with the map expression represent important data for the assessment of geosystem type ecological stability. They also serve as a tool of flood-risk prediction for different applications (in Tatras settlements, forests, marshlands, national nature reserves).

The aim of the paper is to characterize changes in the spatial structure of land cover of the selected area in Tatras National Park in the locality of Vyšné Hágy – Starý Smokovec, based on the analysis of the state of the landscape structure before the wind calamity in November 2004 and after this, employing the methodological procedures CORINE Land Cover. The approached information is important for the needs of the integrated assessment of the researched area and for the landscape planning. It also represents the groundwork for the mapping of the spatial structure of biotopes; and the assessment of the extent of the damage of various types of geosystems by the wind calamity, processed on a large scale. Besides, the paper brings an example of land cover research applying data obtained from remote sensing, field research, and geographical information systems.

2. Study area

The Tatranský Národný Park (Tatras National Park - TANAP) was founded on 1st January 1949 as the oldest national park in Slovakia with an aim to preserve diversity of landscape systems in the Tatras and in the surrounding basins with a variability of biotic and abiotic nature. The area is used namely for recreational and curative purposes, and for scientific research. The

TANAP area is 1,045 km^2 of which 738 km^2 are occupied by its proper area and 307 km^2 by the protection zone (www.lesytanap.sk/01-priroda-tantapu/index.php).

The model area affected by the wind calamity in November 2004 (Fig. 1) is situated between Vyšné Hágy and Starý Smokovec, occupying 36.2 km^2 and representing various landscape systems types. The area for research was limited due to the research area of our VEGA grant project. Tatras settlements situated within the territory are Vyšné Hágy, Nová Polianka, Tatranská Polianka, Tatranské Zruby, Horný Smokovec, Dolný Smokovec and Starý Smokovec. Falťan, Saksa (2007) mapped the neighbouring area in the surroundings of Štrbské pleso. Transport communications cutting through the concerned territory are Cesta Slobody Road and Tatras electric railway. The area lies at the boundary of the geomorphologic unit of Tatras, sub-unit of the East Tatras and a part of the High Tatras (Mazúr, Lukniš, 1980). Its elevation is between 720 and 1,300 m a.s.l.

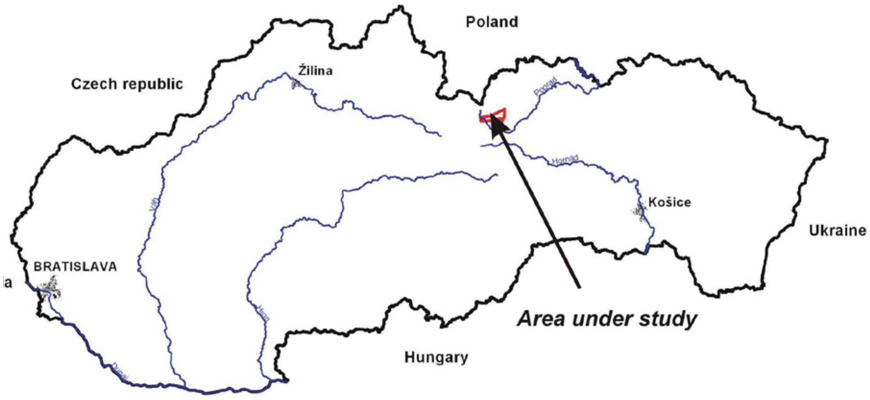

Fig. 1: Area under study

In his phytogeographical classification, Plesník (2002) ranks higher segments of the area, situated above the Cesta Slobody Road, into the coniferous zone, region of the Tatras, subregion of the High Tatras. Lower segments belong to the coniferous zone, the region of Popradská kotlina Basin and the subregion of Tatras foothills. Before the wind calamity, the real vegetation in the area consisted of spruce-bilberry forests and fir-spruce forests, locally with an occurrence of Suiss Pine (*Pinus cembra*). After the calamity, we can find clearings where the calamity wood had been already cleared. In the area of Jamy, east of the Studený potok Brook, some calamity wood had been left to study secondary succession. Dwarf pine and alpine meadows stands are present above the upper forest boundary. In lower areas, we identified a mosaic of mixed forests, mostly consisting of oaks and spruces. Furthermore, non-forest communities of shrubs, mixed covers of pioneer woods were identified. There is also a cover of foothill alders near the electrical railway and ruderal vegetation and a park-growth near the settlements. In the south, a mosaic cover of meadows and pastures and weed-communities of cultivated areas are identified.

Regarding nature and landscape conservation, the Cesta Slobody Road forms a boundary between TANAP and its protection zone. A greater part of territory above the Cesta Slobody Road reaches into national nature reserves such as Štôlska dolina Valley, Batizovská dolina Valley, Velická dolina Valley, Slavkovská dolina Valley, Studené doliny Valleys. The Uhliščiatka, Brezina, Mraznica and Pôš reserves are located below the Cesta Slobody Road.

3. Land cover and its mapping

Land cover is defined as a material expression of land use-related natural and human processes on the Earth surface. It is differentiated spatially on the grounds of its physiognomic and morphostructural features and it indicates the intensity of processes and changes in the landscape. Land cover identification is a primary and necessary condition for the analysis of land use, causes and consequences of land use, assessment of the human impact on the landscape, and for the solution of the problem of ecological stability (Feranec, Oťaheľ, 1999).

Object of land cover research is the ground surface and objects occurring on the ground surface. *Subject* of research is the illustration of the spatial structure of land cover mapping units in maps as well as the narrative characteristics of these. For better understanding of the term *land use*, the equation *land use = land cover + land utilization* (Burley, 1961) can be employed. According to this, land use is a consequence of land cover knowledge and function. Within the landscape research of regional dimension, morphostructural and physiognomic land cover features correspond with the basic functional attributes thus indicating a spatial organization of the cultural landscape. An analysis of land functions is important notably in the categories of the extensively used agricultural, forest and semi-natural landscapes, which are typical for the landscape character in the Podtatranská kotlina Basin and of the Tatras while the ‚materialization' of interests in these characteristics is hardly distinguishable. The recognition of these areas is important also in respect of the determination of the hierarchy of their ecological significance for landscape management and planning (Feranec, Oťaheľ, 2001).

Foreign authors concerned with the identification of land cover types through the use of remote sensing to be mentioned are e.g. Steiner (1962), Anderson (1971), Baker et al. (1979), Allan (1980), Heymann et al. (1994), Bűttner et al. (1998). Since 1991, Slovakia has been participating in the project Land Cover within the programme of European Community CORINE, which sets the creation of a consistent and compatible digital land cover database in Europe as its objectives, working on a scale of 1:100 000 and employing remote sensing methods. Within the project, internationally mandatory categories of land cover forms have been defined. A unitary methodology has been used for the implementation of the CORINE Land Cover project (Heymann et al., 1994), composed of the following essential pieces: preparatory works and the selection of data, colour syntheses (image maps) from satellite image records, analogue interpretation of satellite image maps. A total amount of 31 classes have been identified in Slovakia from the total of 44 basic classes constituting the CORINE Land Cover legend (Feranec, Oťaheľ, Pravda, 1996).

The Institute of Geography of the Slovak Academy of Sciences is currently the Slovak leader in the field of land cover studies. There are several publications that published the remote sensing data (Feranec, Oťaheľ, 1992; Oťaheľ, Feranec, 1993), which have later continued in their work within projects of the European Community CORINE Land Cover (CLC) (Feranec, Oťaheľ, Pravda, 1996; Oťaheľ, Feranec, 1997; Oťaheľ et al., 2000; Feranec et al., 2004). Land cover changes in Slovakia or in the country's selected regions are discussed in the following publications: Oťaheľ et al., 2003; Cebecauerová, Cebecauer, 2004; Oťaheľ et al., 2004. The proposed legend was tested in experimental areas of the Czech Republic, Hungary, Poland and Slovakia between 1995 and 1996 and the fourth level of CLC categories was characterized by Feranec, Oťaheľ (1999). Contemporary results of the land cover research of the whole Slovakia on a scale of 1: 500 000 are presented by Feranec, Oťaheľ (2001) and Feranec, Oťaheľ (2002). Falťan (2000a, 2000b) has elaborated case studies focusing on the mapping of the land cover using the CORINE method. Bičík, Himiyama, et al. (2005) dealt with the understanding of landcover changes in global and regional context. Lipský, Kalinová (2001), Bičík, Chromý (2006) solved the problem of landscape structure changes in selected areas of the Czech Republic. Boltižiar (2007), Olah et al. (2006) have studied the changes of the landscape structure employing the remote sensing and GIS tools. Land cover research problems were discussed by Feranec et al. (2004), Falťan (2005). Oťaheľ, Feranec (2006) present an overview on the development of landuse mapping in the context of Slovakia. Falťan, Saksa (2007) considered the changes of land cover after a wind calamity in the surrounding areas of Štrbské Pleso.

4. Methodological procedures for land cover mapping

In the following text, we discuss methodological procedures that we employed for the production of land cover maps in the area of interest and for the assessment of its changes after the wind calamity in November 2004. We have processed the land cover map and the characteristics of its typological units in accordance with the CORINE method of the land cover mapping, describing in detail the third and the fourth level of the categories of the CORINE Land Cover project. We chose units occurring in the area of interest, of which some names were adjusted with respect to the individuality of the area of interest.

Preparatory stage and interpretation of remote sensing data

In a large-scale research of spatial landscape structure, it is important to process remote sensing data on a scale relevant to employed groundwork maps and planned cartographic outputs. Aerial pictures on a scale of 1: 25 000 employed during the cloudless weather in 2005 were used for the primary identification of land cover categories and their boundaries by visual (analogue) interpretation. These pictures represent a contemporary state of the real spatial landscape structure. Based on them, we established individual land cover patterns with their characteristic texture according to the legend. The pre-calamity land cover was adjusted according to Burda et al. (2005).

Using a foundation topographical map in Gauss-Krűger projection, the projection limits were enhanced for the subsequent field mapping on a scale of 1: 25 000 (The size of the least identified area for the CORINE Land Cover maps is established at 4 ha, e.g. a 4x4 mm square in the map on a scale 1: 25 000 is 1 ha).

Texture represents the area variability in the arrangement of tones in the image. The pattern is a typical alternation of textures, illustrating the spatial arrangement of objects on the ground surface (Feranec, Oťaheľ, Pravda, 1996). Texture characteristics, namely the tone variability and the spatial distribution of point, strip and spot texture components served to associate relative identified areas into hierarchically organized groups.

Field research focused on the identification of land cover categories

Boundaries of the particular areas were updated during the actual field mapping combined with the work with topographical maps on a scale of 1: 25 000. We have also dealt with the identification of typical textures and patterns of images directly on the actual Earth surface with using their spatial coordinate connection by means of GPS technology. In the identification of individual categories of the 3rd level (and in some selected and relevant ones also the 4th level with respect to pre-calamity research) of land cover, our work was ruled by the characteristics of morphostructural and physiognomic features by which the respective areas differ from each other, differentiating the inner heterogeneity of the classes of higher level (Feranec, Oťaheľ, 1999, 2001). Besides the morphostructural and physiognomic features, the division takes into account territorial particularities, too, such as the segmentation of felled-out plots in the concerned regions of the calamitous area to plots totally cut-out without standing trees, with standing trees, or the separate mapping of plots untreated after the calamity with the communities left to spontaneous development as these are important in respect of the research of the secondary succession. We have created our own labels for these categories of the contemporary land cover.

Processing the research results and creation of land cover maps

In this part, we focused on the final classification of the mapped areas into the hierarchical structure within particular categories of the CORINE Land Cover project for the Central Europe, supplemented with some new categories related to the processing of wind calamity. Field research findings enable us to extend the database of landscape characteristics gradually, and to prepare foundations for a more detailed segmentation of mapping units at the fifth level. This segmentation exceeds the extent of the most of the works published in Slovakia so far. We have processed the characteristics of land cover typological units in the area of interest and their spatial structures were displayed in GIS using the ArcView and ArcInfo softwares. Final maps of the land cover before and after the wind calamity are presented on a scale of 1: 50 000.

Digitalization of the maps made it possible for us to use an already created database for further analyses, focused on the quantitative characteristics of land cover changes by comparing the maps produced according to the spatial information on the land cover of the landscape before the wind calamity in November 2004 and after that. We focused on the description of the amount of traverses of particular mapping units, their absolute and relative area.

In the table outputs, we characterize particular mapping units of the land cover before the wind calamity and after the calamity by the number of traverses and by their area size. Changes of the spatial structure of the land cover give a true picture of characteristics of the number of changed traverses, the absolute and relative change of sizes (positive or negative) of particular types of areas of the land cover. GIS ArcInfo tools were used for the analyses.

Our methodological approach was based on the combination of field research methods and remote sensing data. Whereas the first group of methods updates the enlargement of individual land cover mapping units according to actual situation, the second one provides a possibility to significantly precise the occurrence of areas and area distribution of the units according to actual ortophoto-images capturing the physiognomic and morphostructural features.

5. Land cover before the wind calamity

This chapter briefly summarizes the occurrence of mapping units in the area of interest in 2003 (Fig. 2). We state the CORINE Land Cover codes next to their names. The next chapter will bring a closer characteristic of land cover with the description of land cover after the wind calamity.

Artificial surfaces (1) represent segments of cultural landscape most affected by humans. The areas of this category were identified particularly within the settlements of Vyšné Hágy, Nová Polianka, Tatranská Polianka, Tatranské Zruby, Horný Smokovec, Dolný Smokovec, Starý Smokovec and nearby traffic routes. Characteristics of this category distinguishing particular land cover features are as follows: built-up area density, size and shape of buildings, character of supplementary parts of the category (urban greenery), traffic pattern structure, downhill ski tracks and special infrastructure.

Discontinuous urban development (112) represents most areas of this mapping unit in the Tatras settlements and alternates with a mosaic of grasslands, hotel facilities, roads and retail facilities. *Road and rail networks and associated lands (122)* are represented namely by the Cesta Slobody Road connecting the Tatras settlements and by the Tatras electric railway. A mosaic of *green urban areas (141)* is present in the centres and peripheries of settlements. *Sport and leisure facilities (142)* are chiefly represented by ski tracks in the surroundings of Starý Smokovec.

Agricultural areas (2) represent areas with farming production within agricultural cooperatives or private farms. These consist of non-irrigated arable land, pastures and a mosaic of fields, meadows and permanent cultures. Characteristics features of distinction between the respective mapped classes are the method of cultivation and their current use.

Fragments of *non-irrigated arable land (211)* occur south of Smokovecs, on the edge of our area of interest. *Grasslands (meadows and pastures) (231)* consist of grass-herb communities (prevailingly without trees and shrubs) dominated by grasses used for mowing (meadows) and grazing (pastures). They are scattered in the lower parts of the concerned area.

Forests and semi-natural areas (3) represent segments least affected by humans, with the cover of natural forests and the highest level of ecological stability. They covered more than 92% of the area, along with spruce plantations that had suffered most severe damage during the wind calamity. Heterogeneity of the content of mapping units results from physiognomic differences of the respective forest stand types.

Broad-leaved forests (311) were represented by remainders of the original natural vegetation. Preserved fragments of the submontane and montane alder floodplain forests occurred nearby brooks in the valley. Subslope alder stands were present in terrain depressions. *Coniferous forest (312)* represented a greater part of forest stands in the area. Young s*pruce plantations* dominated that had been significantly damaged by the calamity in 2004. In addition, *plantations of pine* and *European larch* were locally present on margins of the forest complexes. In higher elevations, there were forests of the original species composition consisting mostly of *spruce-bilberry forests* that had been less damaged by the calamity. *Mixed forests (313)* consisting of *mixed stands of pioneer tree species*, locally with a mosaic of spruces, pines and maples of discontinuous canopy and conifer plantations, occupy mostly the Southeast of the area – localities of Kopanica, Žákovská poľana. They also stood for a transition between the broad-leaved and coniferous forests. *Transitional woodland-scrubs (324)* represent transitional succession stages between grasslands and climax forest communities as well as clearings overgrown with young individuals of spruce, fir, pine, larch or other species. They occur dispersed namely in the lower-situated part of the area, beneath the Cesta Slobody Road. Before the calamity, larger areas occurred near Kopanica south of Starý Smokovec.

Water surfaces (5), particularly natural watercourses and lakes, are ecologically stabilizing elements of the landscape. Communities of running and stagnant waters are locally and regionally significant biocorridors and biocentres. *Watercourses (511)* belong to biocorridors connecting various biocentres within the area that are important for the migration of organisms. In the concerned area, they are represented by the Studený potok Brook, Štiavnik, Slavkovský Brook, Velický Brook, Batizovský Brook, Háganský Brook, Veľký and Malý Šum and Poprad with its feeders, mapped as linear units. Gravel bars with the pioneer vegetation are present sporadically.

6. Land cover after the calamity

Urbanized and artificial surfaces represent segments of cultural landscape that have been most affected by humans. In the concerned territory, areas of this category were identified particularly within the intravillan of Tatras settlements (Fig. 3).

Discontinuous urban development (112) occupies a greater part of areas in this mapping unit and alternates with a mosaic of grasslands, hotel facilities, roads, retail outlets and gardens in lower situated settlements. This unit includes also buildings in the extravillan, which are used for a whole-year housing and for recreation. Areas of this mapping unit are concentrated particularly in Tatras settlements (Horný Smokovec, Dolný Smokovec, Starý Smokovec, Nový Smokovec, Tatranské Zruby, Tatranská Polianka, Nová Polianka and Vyšné Hágy in the area of interest). Although the wind calamity has damaged some buildings significantly, the size of this mapping unit after the calamity is same as before the calamity (Tab. 1). It is expected that the size of the area will slightly increase after planned activities of developers.

Road and railway networks and associated land (122) represent communications built by humans to provide transport of persons and freight along with adjacent facilities (station buildings, embankments). An important communication (the Cesta Slobody Road) constitutes a transport axis of the concerned area. Along with other communications, it is classified in the *road networks and associated land* mapping unit. A narrow-gauge railway leads parallel to the Cesta Slobody Road, which has in the area of interest a branch leading from the foothills. In the East, it is a railway line from Poprad to Starý Smokovec. Not even this mapping unit of *railway network and associated land* changed its size after the wind calamity.

Agricultural areas are represented by areas with agricultural production within agricultural cooperatives or in the ownership of private farmers. They consist of non-irrigated arable land and permanent grasslands (meadows and pastures) within the area of interest.

Non-irrigated arable land (211) is represented by annually intensively stands of cereals, fodder and root crops occurring on the plateaus of moderately inclined slopes in fragments south of Smokovecs on the edge of the concerned area. Seasonally irrigated fields are parts of the mapping unit, too. Based on the situation before November 2004, the non-irrigated arable land occurred in three segments at the southern border near Malý Smokovec. In the after-calamity period (June 2007), this mapping unit was represented also by three segments whose size increased, however.

categories of landcover	before the calamity			after the calamity			landcover changes	
	areas count	area (ha)	area (%)	areas count	area (ha)	area (%)	area (ha)	area (%)
Discontinuous urban fabric	76	92.65	2.56	76	92.65	2.56	0.00	0.00
Road and rail networks and associated land	9	41.02	1.13	10	41.85	1.16	0.83	0.03
Green urban areas	14	19.80	0.55	15	19.41	0.54	-0.40	-0.01
Sport and leisure facilities	7	13.46	0.37	8	13.67	0.38	0.21	0.01
Non-irrigated arable lands	3	1.80	0.05	3	2.19	0.06	0.40	0.01
Grasslands	70	105.11	2.90	30	34.23	0.95	-70.88	-2.49
Broad-leaved forest	2	2.92	0.08	–	–	–	–	–
Coniferous forest	38	3133.51	86.54	40	400.27	11.06	-2733.24	-96.14
Coniferous forests with local clearings	–	–	–	18	42.35	1.17	–	–
Mixed forests	14	103.43	2.86	–	–	–	–	–
Transitional woodland-scrubs	38	107.01	2.96	72	144.12	3.98	37.11	1.31
Complete clearings	–	–	–	50	2358.81	65.15	–	–
Complete clearings with individual trees	–	–	–	81	413.43	11.42	–	–
Unprocessed calamity	–	–	–	13	57.74	1.59	–	–
∑	**271**	**3620.71**	**100.00**	**416**	**3620.71**	**100.00**	**2843.05**	**100.00**

Tab. 1. Statistical characteristics of land cover changes in selected area after the wind calamity

Grasslands (meadows and pastures) (231) are represented in the area of interest by segments that had been initially overgrown with forests, neighbouring arable land or lying in remote parts of the landscape where climate, slope gradient and accessibility do not offer conditions favourable for tillage. They consist of grass-herb stands dominated by grasses used for cutting (meadows) and grazing (pastures). Before the disaster, they had mostly occurred in the lower situated part of the studied area (below the level of the Cesta Slobody Road, namely in the south and southeast of Starý Smokovec). They were quite often old pastures that had gradually become overgrown within the succession – occurring in the neighbourhood of transitionaly woodland-shrubs. They had occurred in abundance in the form of small clearings in the coniferous forests. After the disaster, the number of segments in this mapping unit decreased by more than a half from 70 to 30 and the area size was reduced by 70 ha. In many cases, the original grasslands were used as gathering places for the processed wood matter, which degraded their standard. After the removal of the processed wood-material, they lost their characteristic feature – grass cover, being classified in the category of complete clearings. Some of them, for example in the area southeast and southwest of Vyšné Hágy were classified as transitional woodland-shrubs. The reason to this change was the change of management methods and gradual overgrowth.

Forest and semi-natural areas represent segments least affected by humans in the concerned territory. These natural forests of the highest ecological stability combine with young spruce plantations most affected by the wind calamity. This major hierarchic land cover unit includes transitional woodland-shrubs, too.

Broad-leaved forests (311) - the calamity had affected these segments in a destructive way. They ceased to exist and the land cover category does not exist any more in the current land cover structure.

Coniferous forests (312) had represented a greater part of stands on the forestland in the territory. Predominant were pure spruce stands in lower situated and central parts of the concerned area, which had been significantly damaged by the calamity in 2004. Marginal to forest complexes, there are local plantations of pine and European larch. At higher elevations, there are forest stands of the original species composition, namely spruce-bilberry forests in the national nature reserves of Štôlska dolina Valley, Batizovská dolina Valley, Velická dolina Valley, Slavkovská dolina Valley and Studené doliny Valleys that had been significantly less damaged by the wind calamity. Locally occurring are fir-spruce forests, too. While the coniferous forests represented more than 87% of land cover in the researched area, they occupy only about 11% today. Islets of this mapping unit are to be found to the north of Tatranská Polianka and Starý Smokovec.

Coniferous forests with local clear-cuts (312a) were singled out as one of specific mapping units characterizing the land cover situation in the researched area after the wind calamity. Their area representation is only about 1%. Islets of this mapping unit we can find north of Tatranská Polianka and Starý Smokovec.

Mixed forests (313) consisting of *mixed stand of pioneer species*, locally also of the alternating spruce, pine and maple groups with a continuous canopy and young coniferous plantations had existed before the calamity either as islet segments in the surroundings of Vyšné Hágy, or, at a greater area extent, in the southern part of the concerned territory east of Tatranská Polianka. The

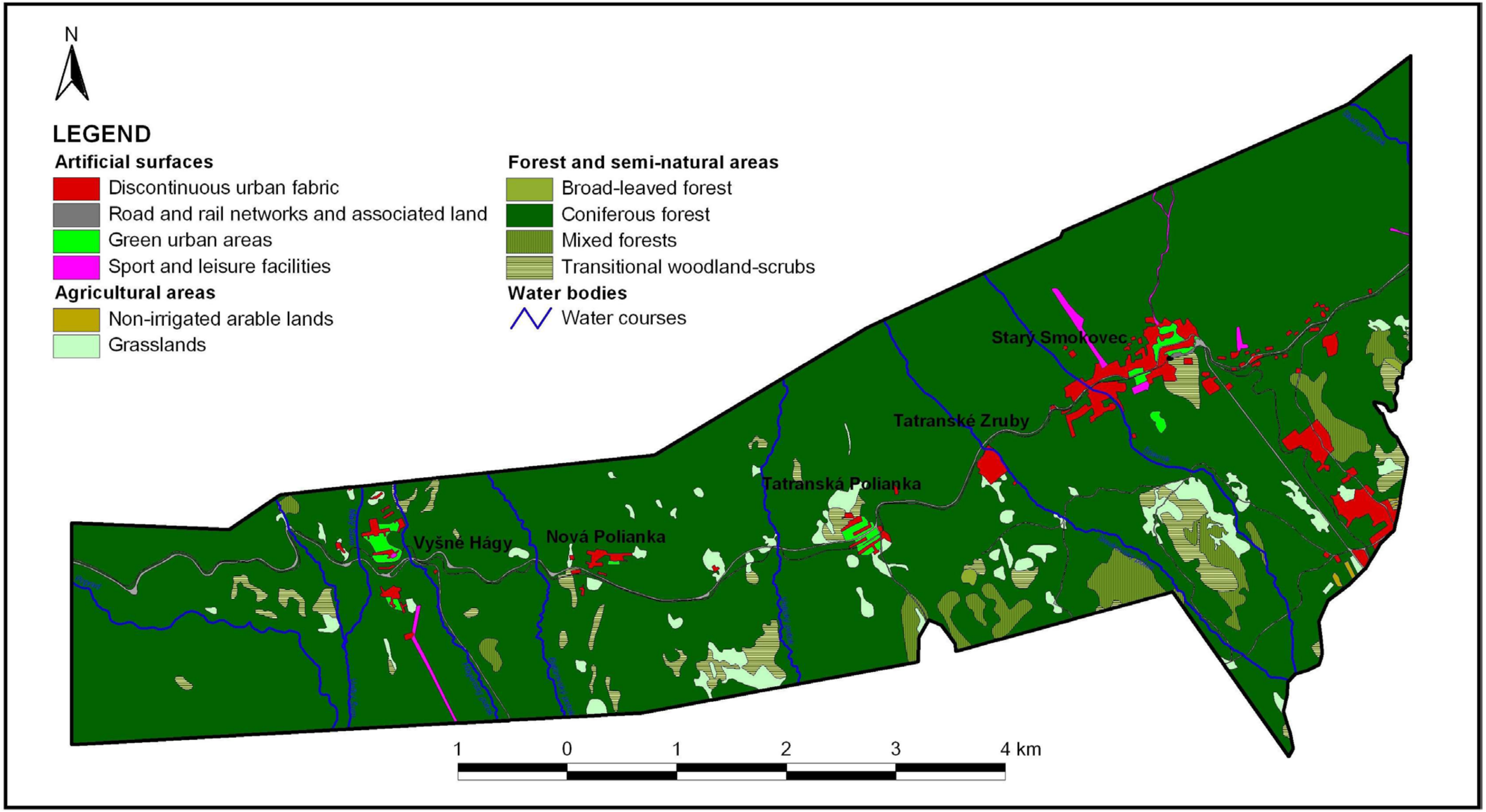

Fig. 2: The land cover before the calamity

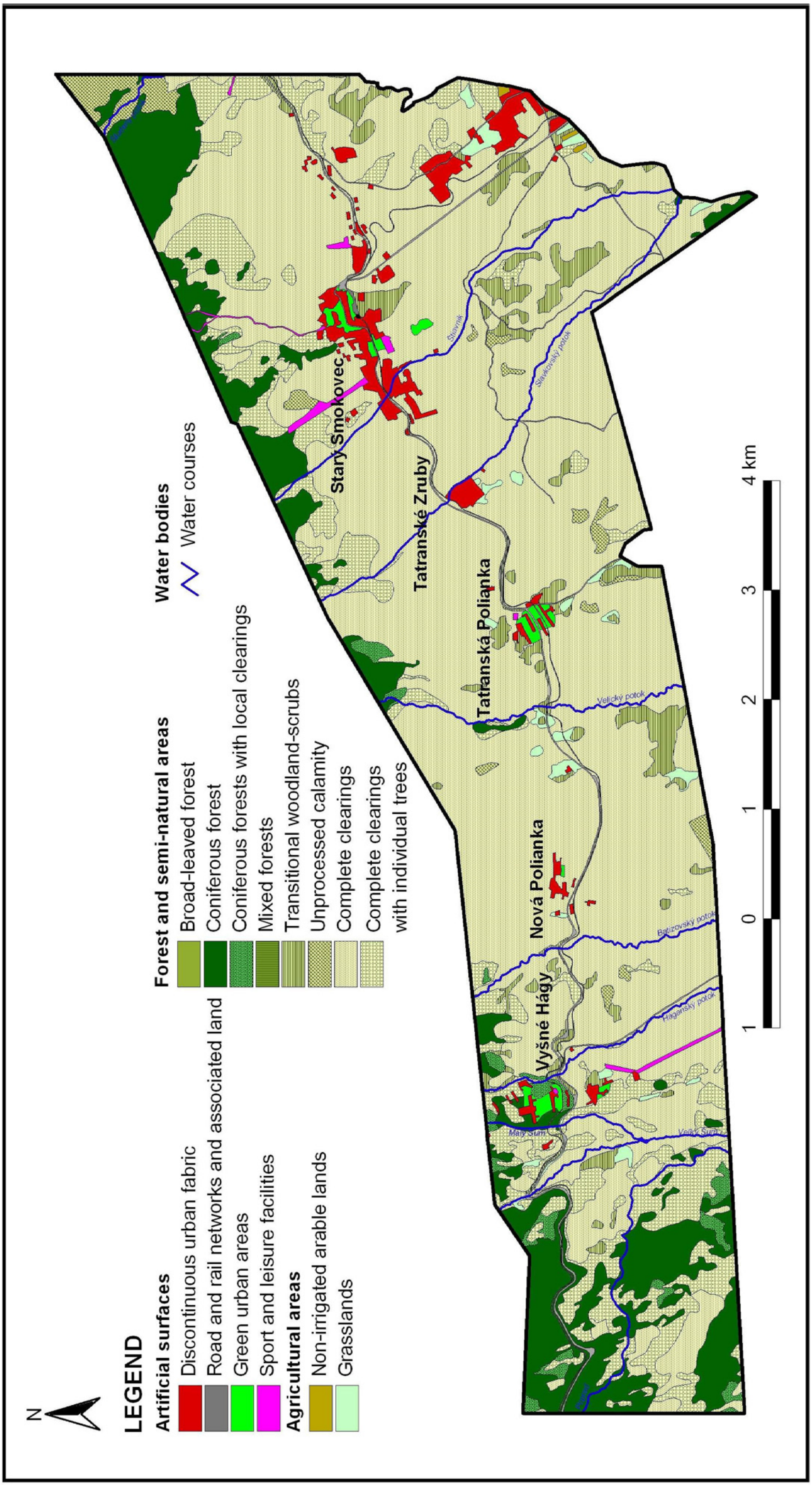

Fig. 3: The land cover after the calamity

wind calamity affected this mapping unit, too, and the mixed forests do not occur in the area interest now.

Transitional woodland-scrubs (324) represent transitional seral stages between grass stands and climax forest communities. This unit also contains young developmental stages of the mixed stands of pioneer tree species with incomplete canopy that we do not consider yet to be forest communities. Before the calamity, they had been scattered in the area in of interest as small- or medium-sized islets. The largest segments of this mapping unit occurred between Dolný Smokovec and Starý Smokovec. Their current size is about 38 ha larger than before the calamity; however, their number has almost doubles. Another segment, on the right side of the Velický potok Brook has joined two former segments, about 1 km beneath the Cesta Slobody Road. Moreover, the number of segments sized about 2 ha has increased significantly.

Complete clearings **(32411)** stand for more than 65% of the researched area. They dominate other categories in the terms of their size and in the stretch Vyšné Hágy – Starý Smokovec they constitute almost a monolithic unit. These plots from which the calamity consequences had been completely removed are overgrown namely by small-reeds *(Calamagrostis villosa)* and chamaerions *(Chamaerion angustifolium),* whose effect on visual perception of the area affected by the calamity in summer (when in bloom) gave to the High Tatras a seasonal attribute of "violet".

Complete clearings with individual standing trees (32412) take up slightly more than 11% of the land cover in the area of interest. They often form kind of a "buffer zone" to the coniferous forests. They are mostly present in areas around Starý Smokovec and Vyšné Hágy (Fig. 4 – see cover p. 4).

Unprocessed calamity (3242) makes only about 60 ha. The largest one of these plots left to spontaneous development lies to the northeast of Starý Smokovec. Smaller islets can be found between the Slavkovský potok Brook and Štiavnik south of Starý Smokovec, below Tatranská Polianka, on the left bank of the Velický potok Brook above the Cesta Slobody Road, between the Háganský potok Brook and Batizovský potok Brook near Vyšné Hágy (Fig. 5 – see cover p. 4). and below the level of the main traffic artery and in the south edge of the researched area at the level of Nová Polianka.

Water surfaces are segments of waters, chiefly natural water streams and lakes that belong to ecologically stabilizing landscape elements, too.

Wate courses (511) belong to the biocorridors connecting various biocentres in the territory that are important for the migration of organisms. In the area of interest, they are represented by the Studený Brook, Štiavnik, Slavkovský Brook, Velický Brook, Batizovský Brook, Háganský Brook, Malý Šum, Veľký Šum and Poprad.

7. Conclusions

Land cover represents a material expression of natural and human processes occurring in a landscape. Its identification provides an information database for subsequent land use analyses and for proposals of ecological stability improvements. In our paper, we have characterized the spatial structure of land cover in the concerned region and its changes due to the wind calamity in November 2004. The researched area represents the plots of spruce forests damaged totally, partially and forest stands without any damage. We have employed the CORINE Land Cover methodology combined with the interpretation of data obtained from remote sensing and field mapping.

Before the calamity, the land cover of the researched area consisted of 11 types of segments at a total size of 36.2 km^2 categorized in 4 main categories: 1. Urbanized and artificial surfaces, 2. Agricultural areas, 3. Forests and semi-natural areas, 4. Water bodies. After the wind calamity, the most significant changes happened in the size of coniferous forests, which has decreased from 3,133.5 ha (86.5% of the whole area under study) to 400 ha (11.1%). In their place, there are now fragments and larger segments of natural mountain spruce forests, especially in the higher situated northern and eastern parts of the researched area. Coniferous forests with local clearings are present mostly between the undamaged forests and the segments damaged by the calamity. Complete clearings occur in the southeast of the area belonging to the Podtatranská kotlina Basin with the incidence of foothill moraine sediments, fluvial and glacifluvial sediments. In total, we have identified 416 segments of land cover categorized in 13 types after the wind disaster.

Young spruce stands and growths of mixed pioneer species together with natural spruce-bilberry forests and fir-spruce forest stands were damaged less than even-aged spruce plantations occurring on sites with similar features of the abiotic environment. Possible reasons are lesser height of tree individuals, their more flexible stems and – unlike in spruce trees growing in the dense canopy - a lower situated centre of gravity. More detailed analyses beyond the extent of this paper will be included in the continuation of our research project.

Acknowledgement:

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DISASTROUS FLOODS IN CENTRAL EUROPE AT THE END OF JULY 1897 AND THE LESSONS LEARNT

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Abstract

The year 2007 marked the 10th anniversary of the natural disaster of July 1997, which affected a number of countries in Central Europe. In the Czech Republic, it was the „flood of the century". One certain analogy was an extreme event that was recorded exactly one hundred years previously, in the summer of 1897. While in the summer of 1997, the summary multi-day records of total precipitation in certain localities were broken, the one-day amount of 345 mm measured at the Nová Louka / Neuwiese station in the Jizerské hory Mts. (780 m a.s.l.) on 29 July, 1897, was not surpassed. Up to the present, then, it is therefore a Czech (and most likely also, at least a Central European) record. The extreme precipitation in the summer of 1897 resulted in unusual flooding that affected a considerable part of Central Europe. In the territory of the current Czech Republic, the floods occurred mainly in the Upper Labe (Elbe) River Basin. The disastrous floods caused immense material losses and took the toll of at least 167 human lives. At the same time, however, they became an impetus for a range of flood-control measures.

Shrnutí

Katastrofální povodně ve střední Evropě koncem července 1897 a poučení z nich

V roce 2007 jsme si připomněli 10. výročí přírodní katastrofy v červenci 1997, která postihla řadu zemí střední Evropy. V České republice to byla „povodeň století". Určitou analogií byl extrémní případ, ke kterému došlo přesně o sto let dříve, v létě 1897. Zatím co v létě 1997 byly na řadě míst České republiky překonány dosavadní rekordy vícedenních úhrnů srážek, jednodenní srážkový úhrn 345 mm z 29.7.1897 na stanici Nová Louka / Neuwiese v Jizerských horách (780 m n.m.) překonán nebyl. Je tedy dodnes českým a pravděpodobně i středoevropským rekordem. Extrémní srážky v létě 1897 způsobily mimořádné povodně ve značné části střední Evropy. Na území dnešní České republiky se vyskytly především v povodí horního Labe.Tyto katastrofální povodně způsobily mimořádné materiální škody a zmařily ve střední Evropě minimálně 167 lidských životů. Současně se však staly impulzem k řadě protipovodňových opatření.

Key words: *disastrous floods, summer 1897, Central Europe, impacts, lessons learnt*

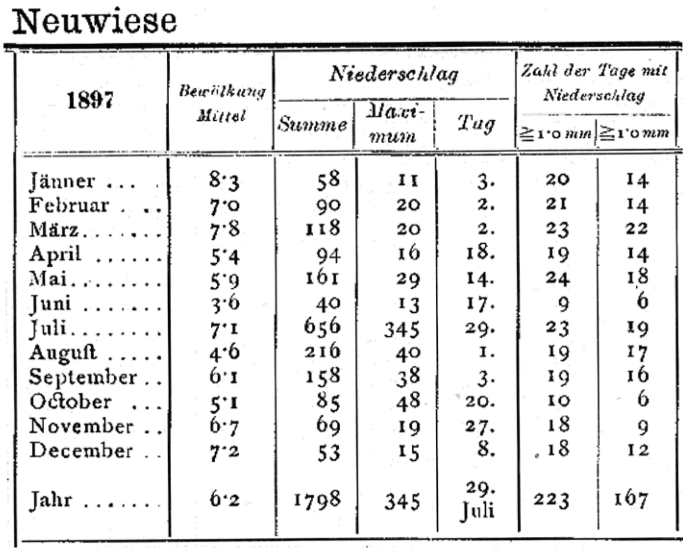
1. Introduction

Not only the turn of 20th and 21st centuries but even the end of the 19th century and the beginning of the 20th century were in the token of severe floods of Central-European significance. While the memory of contemporaries can reach back to the floods of 1997 and 2002, extreme floods remembered a hundred years ago were those of 1897 and 1903 (Munzar, Ondráček, 2003; Munzar, Ondráček, Elleder, 2007).

The old floods are more or less forgotten today although they brought immeasurable misery and losses to the then population living in the affected areas, including a toll of human lives. Floods in summer 1897 that affected a considerable part of Central Europe have become, however, a fountain-head of experience and impetus for flood-control measures, namely for the construction of dam reservoirs. The amounts of atmospheric precipitation that resulted in the then floods are record until now and the 1-day total amount of 345.1 mm at the Nová Louka/Neuwiese station in the Jizerské hory Mts. is a maximum measured in Central Europe that has not been surmounted yet.

2. Causal precipitation

Rain intensity culminated on 29 July 1897 after eight o'clock in the evening. While the multiple-day precipitation was surmounted in the summer of 1997 at a number of places in the Czech Republic, the 1-day total precipitation of 345.1 mm of 29 July 1897 on the Nová Louka/Neuwiese station in the Jizerské hory Mts. (50° 49' N, 15° 09' E, 780 m a.s.l.) was not broken. The concerned record precipitation was first mentioned already the same year in the paper publicized by W. Trabert (1897) and later in the yearbook of the imperial and royal Central Institute for Meteorology and Earth Magnetism in Vienna for 1897 (Tab. 1) published two years later (Jahrbücher, 1899). The original record of this rain-gauging station for July 1897 passed at that time several revisions during which the recorded daily total precipitation amount was not questioned.



Neuwiese

1897	Bewölkung Mittel	Niederschlag			Zahl der Tage mit Niederschlag	
		Summe	Maximum	Tag	≧1·0 mm	≧1·0 mm
Jänner	8·3	58	11	3.	20	14
Februar . . .	7·0	90	20	2.	21	14
März	7·8	118	20	2.	23	22
April	5·4	94	16	18.	19	14
Mai	5·9	161	29	14.	24	18
Juni	3·6	40	13	17.	9	6
Juli	7·1	656	345	29.	23	19
Auguſt	4·6	216	40	1.	19	17
September . .	6·1	158	38	3.	19	16
October . . .	5·1	85	48	20.	10	6
November . .	6·7	69	19	27.	18	9
December . .	7·2	53	15	8.	18	12
Jahr	6·2	1798	345	29. Juli	223	167

Tab. 1: Atmospheric precipitation measured at the Nová Louka / Neuwiese Station in 1897 with a record total amount on 29 July – a detail from the Vienna Yearbook (Jahrbücher 1899)

The extreme character of rains in this region on the concerned day is documented below in Tab. 2 by three highest total precipitation amounts measured in Bohemia and Silesia. As to the dating of the incidence of extreme precipitation at stations on the Silesian side of the Krkonoše (Giant Mts., Riesengebirge) Mts., we have to point out that a historic German yearbook mentions the extreme rain on 30 July which had to do with the fact that unlike in the Austrian meteorological service, total precipitation in Germany was related to the day on which it was measured in the morning.

Although the 1-day total precipitation amounts of 300 mm and higher are exceptional in the European climate, in the summer of 1897 they were recorded even two times: apart from the above-mentioned 345 mm in Nová Louka/Neuwiese, the nearby Jizerka Station (formerly the Wilhelmshöhe Station) in the Jizerské hory Mts. measured 300 mm on the same day! The extreme precipitation amount for 24 hours at the Nová Louka Station is likely until today an at least Central-European record. The extreme character of the then precipitation in this region illustrates for example the data contained in an original rain-gauging record of the Bedřichov/ Friedrichsthal Station (today a part of the town of Špindlerův Mlýn). To the date of 29 July 1897, the last total precipitation amount recorded was „only“ 185 mm but the observer had put in a following remark: *„Three measurements on Day 29. The last one was made late because urgent protective (=flood-protective) works had started, and water in the ombrometer was overflowing, it is therefore possible to judge that the precipitation almost certainly exceeded the amount of 200 mm.“*

In 2002, a new absolute German record was recorded with a daily total precipitation of 312 mm as measured at the Zinnwald-Georgenfeld Station in the Krušné hory /Ore Erzgebirge/ Mts. from the morning of 12th August to the morning of 13th August – which was still 34 mm missing to break the Central-European extreme of 1897.

The distribution of precipitation in the territory of Bohemia for the concerned day is illustrated in Fig.1, which clearly shows that the extreme total precipitation amounts affected namely the Krkonoše Mts. and the Jizerské hory Mts. However, at many other places the daily precipitation exceeded 100 mm.

Total precipitation Amount [mm]	Date	Station	Altitude [m a.s.l.]	Country
345	29. July 1897	Nová Louka / Neuwiese	780	CZ
300	29. July 1897	Jizerka / Wilhelmshöhe	870	CZ
266	29. July 1897	Pec pod Sněžkou / Riesenhain	812	CZ
239	29. July 1897	Śnieżka / Schneekoppe	1603	PL
225	29. July 1897	Schronisko księcia Henryka / Prinz Heinrich Baude	1400	PL
220	29. July 1897	Kościól Wang / Kirche Wang	873	PL

Tab. 2: The highest 1-day total precipitation amounts measured in the Czecho-Polish borderland region on 29 July 1897 (in mm)

As far as synoptic causes to the extreme precipitation amounts are concerned, it was in fact a cyclone advance along the Vb trajectory in the sense of van Bebber's classification. On 28 July, an extensive low pressure area developed above Central Europe with three centres (1005 hPa) over the northern part of the Adriatic Sea, Hungary and southern Poland, which „merged" into one centre (1006 hPa) north of the High Tatras Mts. on 29 July. Subsequently, an irregular displacement occurred of the cyclone centre in retrograde manner to the west and south-west.

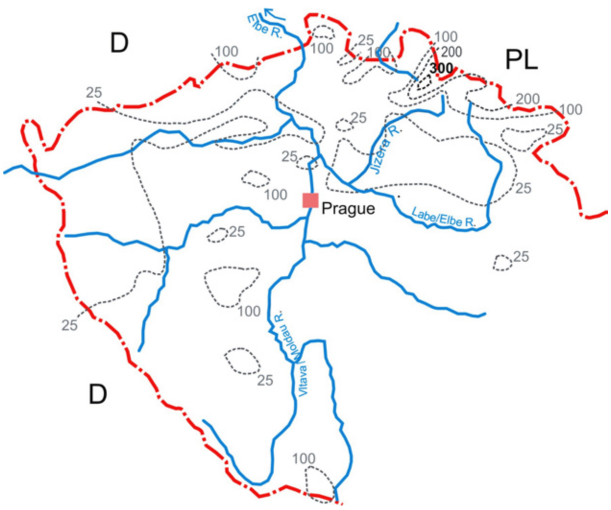


Fig. 1: The map of one-day precipitation isohyets in Bohemia on 29 July 1897 in mm (According to "Příspěvky ku hydrografii Rakouska, 1898", drawing: E. Kallabová)

3. Flood discharges in July 1897

One of characteristic features of the high water at the end of July 1897 was its large extent. Flood waves on watercourses were recorded nearly across the entire territory of the today's Czech Republic. Following tables bring data of selected culmination stages and discharges derived for the flood of 1897 in the territory of Czechia and Saxony. The data are arranged by individual major river basins.

The flood in July 1897 occurred almost across the entire territory of the today's Czech Republic and reached the highest extreme on the upper Labe /Elbe R. basin. Inundations in the basin were rather exceptional. The disastrous situation on streams flowing from the Krkonoše Mts., namely on the upper Labe /Elbe River itself and on its left-bank tributary Úpa R. was compared to apocalypse. The extreme character of inundations corroborates the extremity (return period) established for culmination discharges derived on the Labe /Elbe R. at the Labská Station (below Špindlerův Mlýn) and on the Úpa River at the station in Horní Maršov. According to Brázdil et al. (2005), the two localities had experienced floods that occur on average once in a thousand years. Some hydrologists argue that the return period was not that long. However, an agreement exists in any case that the recurrence interval was greater than a hundred years. The hundred-year floods were recorded also on other stations situated several tens kilometres downstream (in Česká Skalice on the Úpa R. and at the Království Station on the Labe/Elbe R.). The flood on the Úpa River in 1897 has not been surmounted until today and represents the highest extreme recorded in the watershed. Any other flood on this river the size of which would at least near the one of 1897 is not known. On the upper Labe /Elbe R., the flood of 1897 was surmounted in the entire period, which had passed – i.e. in 110 years, only once in 2000 as measured at the Království Station when the Labe /Elbe R. culminated on 9 March 2000 with a discharge of 375 $m^3.s^{-1}$ while on 30 July 1897 the discharge was „only" 330 $m^3.s^{-1}$.

In terms of recurrence interval, the flood in July 1897 was classified as a 50-100 year flood on the lower Jizera River reach (Tuřice Station) as well as on the upper Jizera River reach (stations in Železný Brod and Vilémov). Extremities of higher elevations on the Jizera R. were not established. As to the mountain tributaries of Jizera R. – the left-bank Mumlava R. flowing from the Krkonoše Mts. and the right-bank Kamenice R. descending from the Jizerské hory Mts., the floods in 1897 were 100-year floods.

The progress of flood on the Jizera River in Železný Brod is apparent from the original monthly water-gauge

Watercourse	Station	Culmination discharge [$m^3.s^{-1}$]	Date	Extremity (return period) [years]
Labe /Elbe R.	Labská	200	29. July 1897	>100
Labe /Elbe R.	Království	330	30. July 1897	100
Úpa R.	Horní Maršov	326	30. July 1897	>100
Úpa R.	Česká Skalice	313	30. July 1897	100
Jizera R.	Vilémov	330	30. July 1897	50-100
Jizera R.	Železný Brod	630	30. July 1897	50-100
Jizera R.	Tuřice	650	31. July 1897	50-100
Jizera R. tributaries-				
Mumlava R.	Janov	180	30. July 1897	100
Kamenice R.	Josefův Důl	130	30. July 1897	100
Vltava /Moldau R.	Praha	2090	31. July 1897	10
Labe /Elbe R.	Děčín	2670	2. August 1897	5-10

Tab. 3: Selected culmination discharges of the flood in 1897 in the Czech part of Labe / Elbe River Basin

report (Fig. 2) as well as from the special water-gauge report. While the water level at 6.00 o'clock PM was on zero of water gauge on 27 July, three days later, on 30 July at 6.00 AM it culminated at 400 cm above zero. The special report contains further interesting information, too. An observer reported that the water level could not be observed from 7.00 o'clock PM on 29 July because the access to water gauge was impossible and water was rising continually until the next morning. In the conclusion of his report, the author informed that the staff gauge was only 320 cm in height, and that he had to do the measurement by using an auxiliary meter installed next to it, when the water level height in the Jizera R. reached 400 cm. The conclusion was that a new, higher staff gauge was necessary.

On the Jizera River, some floods are known comparable as to their size with the disaster of 1897. Nine years earlier, at the beginning of August 1888, another disastrous flood occurred on the Jizera R. whose culminations were later established at several places. The culmination discharges on 3 August 1888 in Železný Brod and Vilémov were 664 m^3.s^{-1} (on 30 July 1897 „only" 630 m^3.s^{-1}) and 340 m^3.s^{-1} (on 30 July 1897 „only" 330 m^3.s^{-1}), respectively. In these localities, the flood of 1897 had not reached the culmination discharge of the flood in year 1888 but it had got very close. On the Jizera River in Železný Brod, i.e. below the confluence of this river with its important tributary Kamenice R., these two floods of 1888 and 1897 were surmounted by another flood – in 1978. On 9 August 1978, the Jizera River culminated at a discharge of 704 m3.s-1. The reason to the extreme flood event was a fact that culmination discharges of flood waves from the Jizera R. and the Kamenice R. met at this place nearly in the same moment (Kafka-Vašátko, 1997). Nevertheless, the flood in 1897 is the highest extreme recorded on the lower reach of Jizera R.(Tuřice Station) and on the Kamenice R. until these days.

In July 1897, floods occurred also in the Vltava (Moldau) River basin. Their culmination discharges largely did not exceed the value of 20-year flood discharge. Müller and Kakos (2003) brought attention to an interesting fact when comparing the last two greatest floods on the Vltava/Moldau R. in Prague in 1890 and 2002 with that of 1897. The average causal precipitation in the Vltava R. basin that caused the flood in 1897 was higher not only than the precipitation in 1890 but even higher than the precipitation in 2002. However, regarding the fact that in July 1897 the total precipitation amount was distributed into several days and the saturation of the watershed by previous rains was lower, the Vltava River in Prague culminated on 31 July 1897 at a discharge of „only" 2,090 m^3.s^{-1} while in 1890 and 2002 the culmination discharges were 3,980 m^3.s^{-1} and 5,160 m^3.s^{-1}, respectively.

The Labe /Elbe River in Děčín, i.e. in the final profile of the Czech part of its basin, culminated as late as on 2 August 1897 at a discharge of 2,670 m3.s-1, which indicates that the flood was of size returning on average once in five to ten years.

Further downstream the Elbe R., in Dresden, Germany the situation was still similar to that in Děčín. The flood wave however began to grow on the lower reach of the river due to left-bank Elbe River tributaries dewatering the Saxon side of the Krušné hory/Ore/Erzgebirge Mts. In July 1897, the extreme precipitation fell not only in the Jizerské hory Mts. and in the Krkonoše Mts., but also in the Krušné hory Mts. The precipitation caused extreme floods on Saxon watercourses. Their culminations were measured on a range of water gauges that had already existed there. The comparison of these culminations with other cases of high water clearly shows the extreme character of the flood in 1897 on the streams in Saxony. If the extreme had not been surmounted by inundations in 1954, then this happened only at the time of most

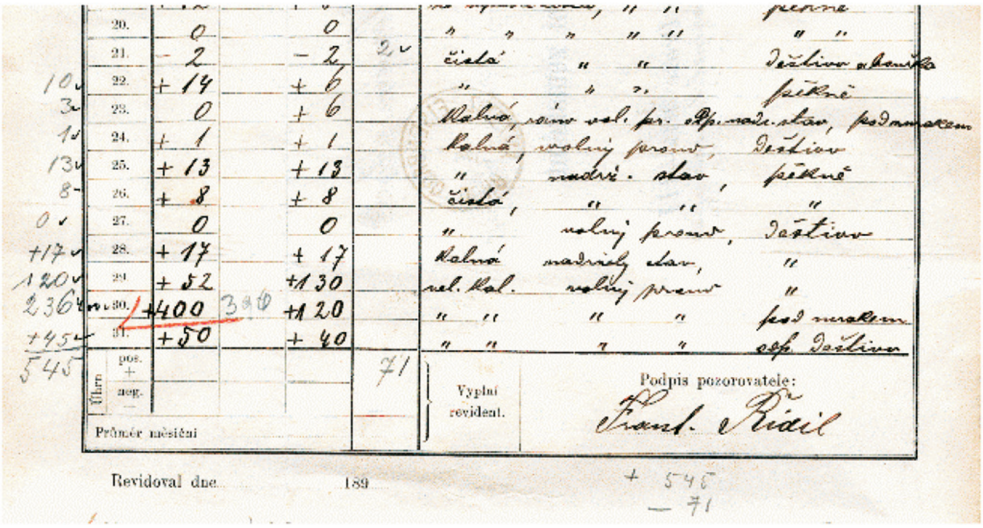


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Fig. 2: Water stages on the Jizera River recorded at the end of July 1897 at the Železný Brod Station – a detail from the original monthly water-gauge report (Archives of the Czech Hydrometeorological Institute)

Station / River	Year		
	1897	1954	2002
Grimma / Mulde R.	490	508	752
Golzern / Mulde R.	657	700	905
Zwickau-Pölbitz / Zwickauer Mulde R.	415	466	476
Rochlitz / Zwickauer Mulde R.	412	528	605
Aue / Schwarzwasser R.	360	382	452
Nossen / Freiberger Mulde R.	388	321	467
Lichtenwalde / Zschopau R.	458	384	636

Tab. 4: Culmination water level heights (in cm) of three large floods in the watershed of Mulde R., the left-bank tributary of the Elbe R. The flood of 1897 is one of the greatest flood events that occurred on rivers in Saxony in the period of water level gauging (according to Büttner, 2004)

extreme flood events in year 2002, i.e. after as many as 105 years. Thus, the flood of 1897 ranked with the three greatest flood events in Saxony in the period of water level gauging (Tab. 4).

The fact is corroborated also by a number of flood marks that had been preserved in Saxony at many places. Flood marks on the wall of mill in the town of Döbeln (on the Freiberger Mulde River) indicate for example that the culmination of the flood from summer 1897 was surmounted only at night from the 12th to 13th August 2002. Flood marks in the town of Grimma on the Mulde R., a left-bank tributary of the Elbe R., show that larger floods had occurred there only twice since year 1897 – in 1954 and 2002 (Fig. 3).

As to flood marks preserved from 1897 in Bohemia, their documentation has not been accomplished yet. Marks reminding us of the flood had been preserved for example in Turnov, Jablonec nad Jizerou (Fig. 4), Bílý Kostel (Fig. 5) and at some other places. Interesting is also the evidence about the culmination of the Úpa R. on a memorial near the village of Říkov. This flood memorial reminds us of the dramatic event that happened during the flood. The text on the monument explains that an apple tree had been standing at that place on which ten local inhabitants saved their lives (Munzar et al., 2006).

On the Jizera River, there are flood marks in several localities reminding extreme events on this river in the 19th and 20th centuries, which unfortunately slowly disappear because they are not currently renovated. A house corner in Jablonec nad Jizerou bears a reminders of as many as four flood events from 1888, 1897, 1915 and 1978. The flood event of July 1897 depicted by us was most severe of those four cases.

A rare reminder of the flood in summer 1897 is a mark in the village of Bílý Kostel. Exceptional about this flood mark is that it is placed inside a church and that it occurs in the Odra (Oder) River basin in Bohemia, thus documenting overflow in the Czech section of the Lužická Nisa (Lausitzer Neiße, Nysa Łużycka) River between the town of Liberec and the state borders of three countries (Czech Republic, Poland and Germany).

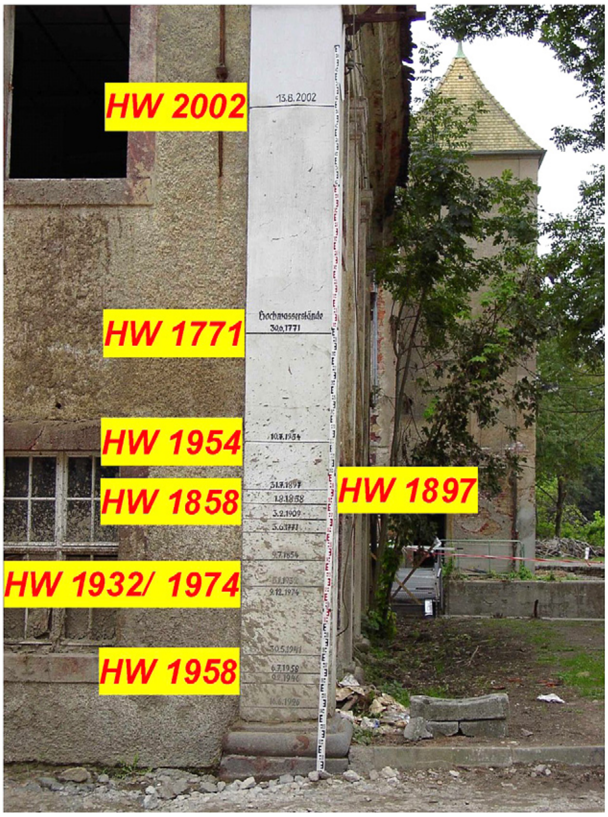


Fig. 3: Flood marks on a house corner in the town of Grimma, Saxony illustrating the culmination of floods on the Mulde River (Photo: U. Büttner)

Extreme floods were recorded in July 1897 in the Odra/Oder River basin, too. Data on culmination discharges and their extremities in the mountain areas of Jeseníky Mts. and Beskids Mts. are however not available from the watershed of the upper Odra R. in northern Moravia and in Czech Silesia. The culmination discharges for the Odra River and its tributaries Opava R. and Ostravice R. were derived only in the downstream-situated localities of Opava and Ostrava regions. Here, the floods of July 1897 were estimated as high water occurring on average once in two to five years (Tab. 5).

Later on, the flood in the today's Poland (the then Prussia) gradually acquired strength due to water from left-bank Odra (Oder) tributaries draining the Sudeten mountain ranges.

Fig. 4: Flood marks on the Jizera River in Jablonec nad Jizerou (Photo: J. Luštinec)

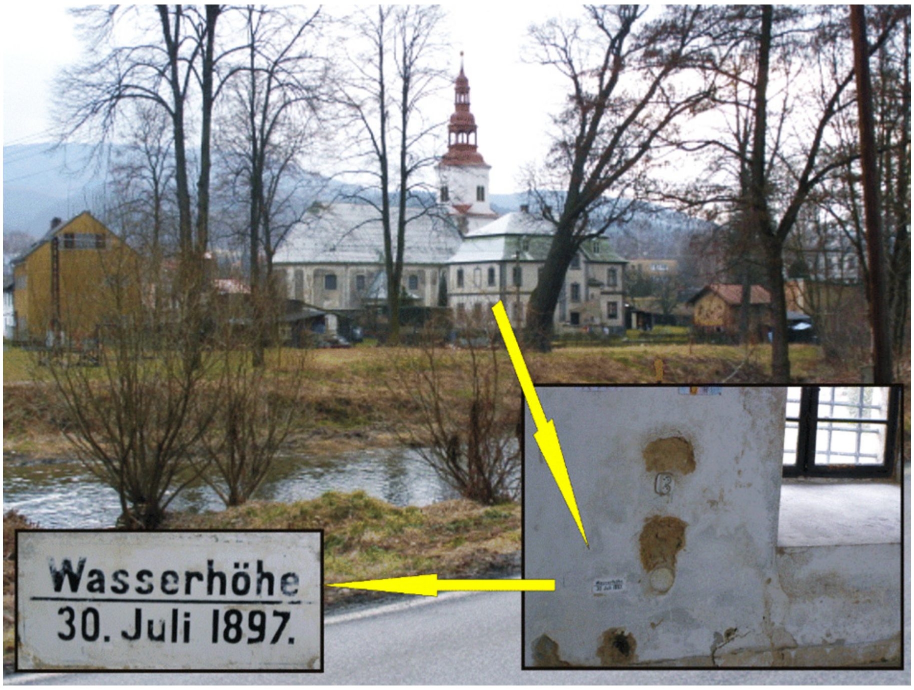


Fig. 5: Flood mark inside the church in the village of Bílý Kostel (Photo: J. Formánek)

Severe floods occurred in the basin of Nysa Kłodzka R., one of the left-bank Odra /Oder R. affluents. The Nysa Kłodzka R. drains the basin of Kłodzko and the adjacent mountains, among other things also the northern side of Králický Sněžník Mts. and the Jeseník region on the Czech territory. The extreme flood event in question occurred in July 1897 also on the right-bank tributary of the Nysa Kłodzka R. – on the Bělá River, which drains the northern Silesian part of Hrubý Jeseník Mts. A water-gauge had existed in the town of Jeseník on the Bělá R. already in 1890. Although the water-gauge was destroyed during the flood toward the end of July 1897, the culmination water level had been recorded. The river of Bělá in Jeseník culminated on 30 July 1897 at an appreciable water level of 450 cm (Řehánek, 2004). However, the value of the culmination discharge at that station was unfortunately not found in the database or in the archives of CHMI (Czech Hydrometeorological Institute), if it had been derived at all.

The most severe floods occurred in the Odra/Oder River basin in July 1897 on watercourses flowing from the Krkonoše Mts. and from the Jizerské hory Mts. In Bohemia, it was on the Lužická Nisa /Lausitzer Neiße R.

Watercourse	Station	Culmination discharge [$m^3.s^{-1}$]	Date	Extremity (return period) [years]
Odra/Oder R.	Svinov	266	30. July 1897	>5
Odra/Oder R.	Bohumín	600	30. July 1897	2-5
Opava R.	Opava	130	30. July 1897	>5
Opava R.	Děhylov	212	31. July 1897	<5
Ostravice R.	Ostrava	353	2. August 1897	2-5
Lužická Nisa/ Lausitzer Neiße R.	Liberec	140	30. July 1897	<100

Tab. 5: Selected culmination discharges during the flood of 1897 in the Czech part of the Odra (Oder) River Basin

Watercourse	Station	Culmination discharge [$m^3.s^{-1}$]	Date	Extremity (return period) [years]
Morava/March R.	Raškov	92	30. July 1897	<10
Desná R.	Šumperk	80	30. July 1897	<10
Vsetínská Bečva R.	Vsetín	166	29. July 1897	<2
Rožnovská Bečva R.	Valašské Meziříčí	240	29. July 1897	>10
Bečva R.	Teplice n. Bečvou	676	30. July 1897	>20
Bečva R.	Dluhonice	654	30. July 1897	<20

Tab. 6: Selected culmination discharges of the 1897 flood in the Morava / March River Basin

and on the Polish (resp. Prussian) side of the mountains mainly on the Bobr/Bober R. and its left-bank tributary Kvisa/Queis R. The culmination discharge of the flood in 1897 on the Czech part of the Lužická Nisa R. was derived only at the Liberec Station. According to these records, the river culminated on 30 July 1897 at a discharge of 140 $m^3.s^{-1}$, which is a value comparable with the 100-year flood discharge, which amounts to 150 $m^3.s^{-1}$ in this locality. On the Czech part of the Lužická Nisa R., the flood event of 1897 has not been surmounted until today. Of older flood events as documented by flood marks, a flood that could be compared with it is that of 1858 at least in terms of the culmination height. According to flood marks in Chotyně, the flood in 1858 ought to have been even higher, in Chrastava on the opposite.

It follows from Table 6 that in the Morava/March R. basin the greatest flood event in terms of extremity in July 1897 occurred on the lower reach of Bečva River. The stations in Teplice nad Bečvou and Dluhonice recorded approximately a 20-year flood. Data available for the two head-waters of the Bečva River clearly show that the Rožnovská Bečva River was much more flooded in July 1897 than the Vsetínská Bečva River. While the flood on the Rožnovská Bečva R. was classified as a more than 10-year flood in its final profile in the town of Valašské Meziříčí, the Vsetínská Bečva R. in the town of Vsetín was at a level of hardly 2-year flood.

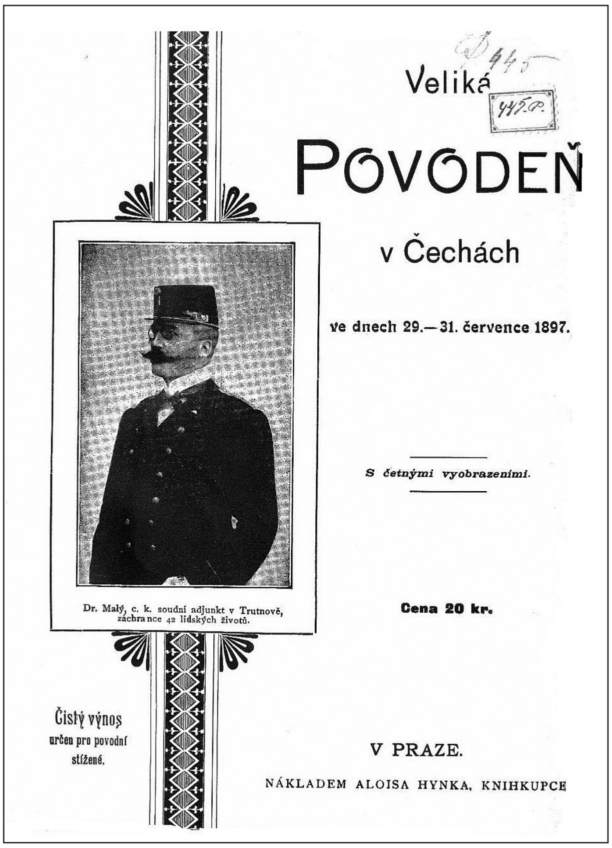
Extreme flood events occurred also in the upper Morava/ March R. basin on streams dewatering the southern Moravian side of the Králický Sněžník Mts., Rychlebské hory Mts. and Hrubý Jeseník Mts. High waters were recorded in July 1897 namely on the upper Morava River itself and on its left-bank tributaries, namely on the Desná River. Culmination discharges for the flood on the upper Morava R. were established in Raškov (likely based on values measured at the station in Ruda nad Moravou) and for the flood on the Desná R. in Šumperk. In both cases, the concerned discharges were of about 10 year flood. On the Desná River, the flood of 1897 markedly showed in the river floodplain morphology and troughs created by floodwaters in July 1897 are still apparent on the river valley floor. Origin of these channels during the flood is dated by establishing the age of trees (Hrádek, Malik, 2007).

4. Flood impacts

Shortly after the extreme flood disaster, a range of period publications was issued depicting its course and extensive losses in Bohemia, Saxony and Silesia. After more than 110 years, the publications provide valuable information about the flood impacts.

The print entitled as a“Great Flood in Bohemia in 29-31 July 1897“ was issued by A. Hynek in Prague in the Czech language and receipts from its sales were meant for inhabitants affected by the flood. On the front page, there is a photograph of Dr. Malý, court adjunct in Trutnov, who rescued 42 human lives during the flood (Fig. 6). However, the publication does not depict only the flood impacts in Bohemia – at the end, it briefly mentions also the situation in Moravia, Silesia, in some other Austrian lands and in Germany.

Two more occasional prints were published in Bohemia in the German language: one in Liberec - „Flood disaster of 30-31 July in the area of Jizerské hory Mts., Krkonoše Mts. etc.“ (Fig. 7), and the other one in Jánské Lázně - „Flood disaster in the valley of rivers Úpa and Labe/ Elbe from 29-30 July 1897“ (Fig. 8). In Silesia, in the town of Jelenia Góra/Hirschberg on the northern side of the Krkonoše Mts., H.F. Grabow Publishers issued a print



Veliká
POVODEŇ
v Čechách
ve dnech 29.—31. července 1897.

S četnými vyobrazeními.

Dr. Malý, c. k. soudní adjunkt v Trutnově,
záchrance 42 lidských životů.

Cena 20 kr.

Čistý výnos
určen pro povodní
stížené.

V PRAZE.
NÁKLADEM ALOISA HYNKA, KNIHKUPCE

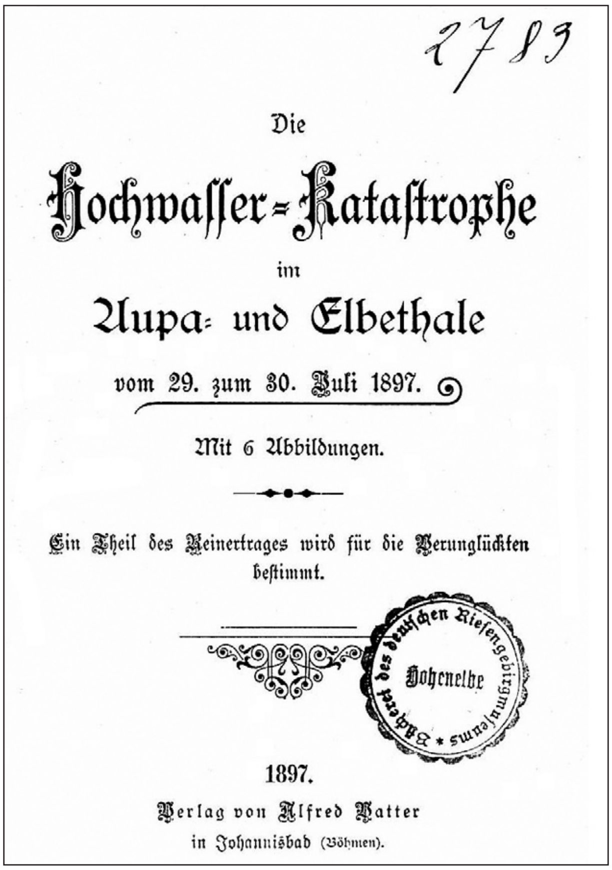
Fig. 6: Front page of the occasional print„Great Flood in Bohemia in 29-31 July 1897“

Die
Hochwaſſer-Kataſtrophe
vom 30. und 31. Juli 1897
im
Gebiete des Iſer- und Rieſengebirges etc.

Mit 12 Abbildungen
nach Aufnahmen der Herren k. k. Kammerphotograph Ferdinand Stracke
und Marcell Stollovšky in Reichenberg.

Reichenberg.
Druck und Verlag von Gebrüder Stiepel.
1897.

Fig. 7: Front page of the occasional print „Flood disaster of 30-31 July 1897 in the area of Jizerské hory Mts., Krkonoše Mts. etc.“ (Liberec/Reichenberg 1897)

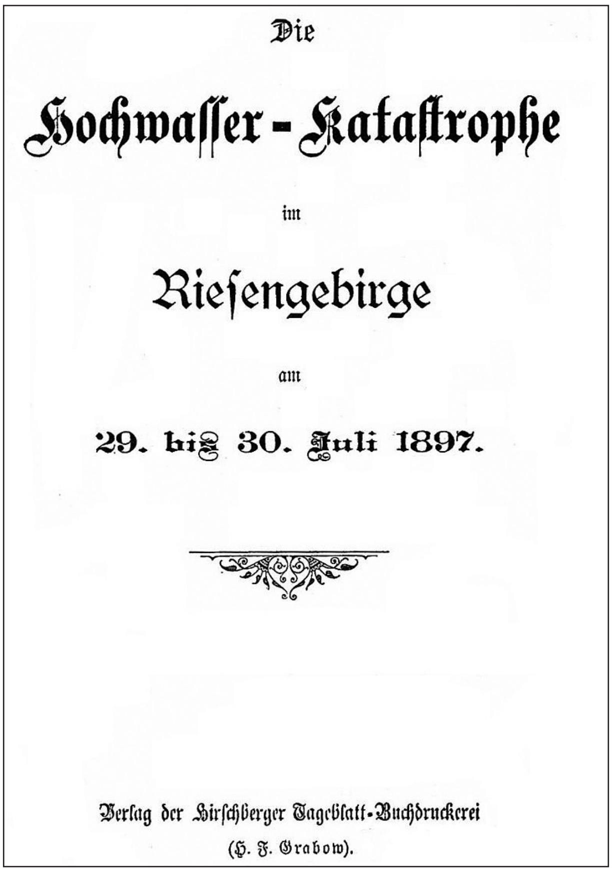


Die
Hochwaſſer-Kataſtrophe
im
Aupa- und Elbethale
vom 29. zum 30. Juli 1897.
Mit 6 Abbildungen.

Ein Theil des Reinertrages wird für die Verunglückten
beſtimmt.

1897.
Verlag von Alfred Watter
in Johannisbad (Böhmen).

Fig. 8: Front page of the occasional print „Flood disaster in the valley of rivers Úpa and Elbe from 29-30 July 1897“ (Jánské Lázně/Johannisbad, Bohemia 1897)



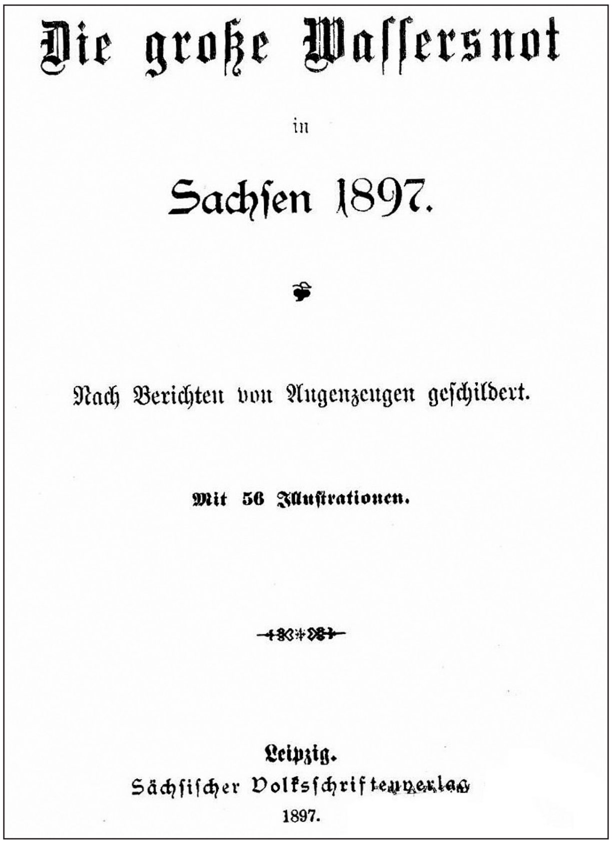
Die
Hochwaſſer-Kataſtrophe
im
Rieſengebirge
am
29. bis 30. Juli 1897.

Verlag der Hirſchberger Tageblatt-Buchdruckerei
(H. F. Grabow).

Fig. 9: Front page of the occasional print „Flood disaster in the Krkonoše Mts. 29-30 July 1897“ (Jelenia Góra/Hirschberg 1897)

titled „Flood disaster in the Krkonoše Mts. on 29 and 30 July 1897" (Fig. 9). The extensive book „Great Flood in Saxony 1897" published in Leipzig (Fig. 10) is concerned with Saxony as suggested by its title. A reprint of this work was published in Germany after the disastrous flood in August 2002 in order to remind contemporaries of the historic flood that has been one of the most severe flood extremes at many places in Saxony until these days.

The flood caused huge material losses that we document by several historic photographs from Bohemia, Silesia and Saxony. On the Czech part of the Krkonoše Mts., they are documented e.g. in photographs made by F. Joffe (Fig. 11).



Die große Waſſersnot

in

Sachſen 1897.

Nach Berichten von Augenzeugen geſchildert.

Mit 56 Illuſtrationen.

Leipzig.
Sächſiſcher Volksſchriftenverlag
1897.

Fig. 10: Front page of the occasional print „Great Flood in Saxony 1897" (Leipzig 1897, photo reprint 2002)

Figs. 12-13 depict the situation on the Polish side of the Krkonoše Mts. in the town of Kowary (former Schmiedeberg) in the watershed of Bober R., the left-bank tributary of the Odra /Oder R. The town of Kowary affected by the flood was visited on 21 August 1897 by German Empress Auguste Victoria (Fig. 14). Prior to her visit, the Empress addressed by her letter (sent from the summer residence of the Prussian Imperial family near Kassel) sororities to encourage them to actively participate in the rectification of flood damages, in which she also requested from them a written report. The letter reads as follows: *„The severe affliction of Silesia as well as of other parts of our home country fills me with grievance and pain. To my real satisfaction, the National sorority has commenced in the concerned province immediate assistance in accordance with the intentions and spirit of its enlightened lady founder. I am convinced, however, that solidarity will be deeply felt in all other royal provinces, and it is my cordial wish that all provincial and daughter sororities commence with respect to the extent of the accident collections to support sister unions in their most likely long-term activity. I ask the presidium to issue necessary orders and to gather received amounts on the supply and use of which a committee established to deal with the affair will report to me."*
Wilhelmshöhe, 15 August 1897
Auguste Victoria
For the attention of the National Sorority Berlin

Fig. 11: Damages after the flood on the Úpa River in July 1897 in the village of Velká Úpa (Archives of P. Scheufler)

Fig. 12: Kowary after the flood in summer 1897 (Archives of K. Sawicki)

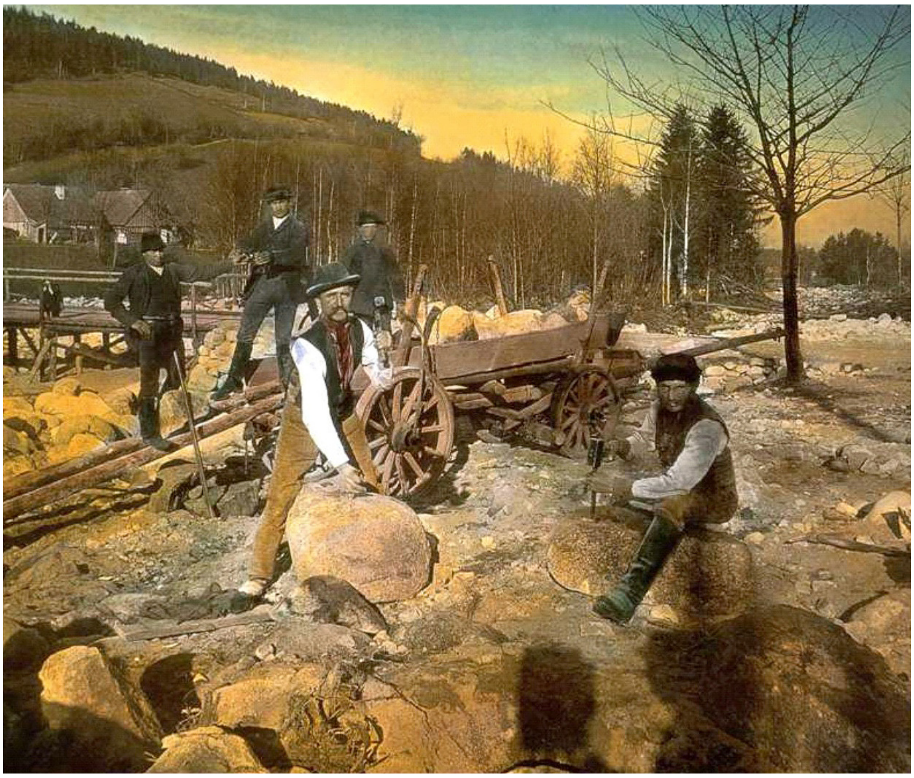


Fig. 13: Rectification of flood damages in Kowary. The weight of boulders that were easily handled by water streams was beyond the modest technical possibilities of those times and workers had to break them before transport (Photo from the collections of the Krkonoše Museum in Jilemnice)

Flood impacts were of various kinds. On the Saxon side of the Krušné hory/Erzgebirge Mts. even the ore mines were affected with a mine blow in Rotschönberger adit. The sandstone vaulting broke down at night from the 30th to 31st July 1897 and the tunnel was choked with the rock at a length of 578 m up to a height of 2.35 m. The clearance took 2 and a half-year (Fig. 15).

The main evidence to destructive flood impacts may be also data on casualties. Analyses of historic and later documents and records suggest that the flood took a toll of 120 human lives only on the Czech part of the Krkonoše Mts. Of these, the raging element took 8 human lives in the village of Pec pod Sněžkou and brought to death 17 persons in the village of Dolní Maršov situated on the Úpa River. Having had refused to obey the police and mayor who called them to leave in time, they perished in the house where they prepared wedding, which collapsed during the flood. Later, a memorial was erected at the place (Fig. 16). Victims documented so far on the Czech part of the Krušné hory/Erzgebirge Mts. amount to 4; on the German side, there were altogether 23 deaths.

As to Silesia, Fischer (1898) claims that the number of deaths was at least 28. Main reason was considered both the fact that the high water arrived at night and the badly organized flood warning among villages. Also, in spite of the fact that water level in streams had considerably raised, people probably believed that water would not overflow because no extreme floods had occurred in the region since 1888.

5. Lessons learnt from the flood disaster in summer 1897

The disastrous flood had become an impetus to a whole range of precautions in all affected countries and regions. Numerous acts of law and flood-control regulations were issued and a decision was made on hydraulic engineering works that would contribute to regulate extreme discharge volumes and to abate future flood damages.

In the Jizerské hory Mts. for example a unique project for the construction of dam reservoirs came to existence. Initiators were local entrepreneurs who founded in 1899 a „Water cooperative for the regulation of watercourses and construction of valley dam lakes in the basin of Zhořelecká (Lužická) Nisa/Görlitzer (Lausitzer) Neisse

Fig. 14: Visit paid by German Empress Auguste Victoria after the flood to Kowary (Archives of K. Sawicki)

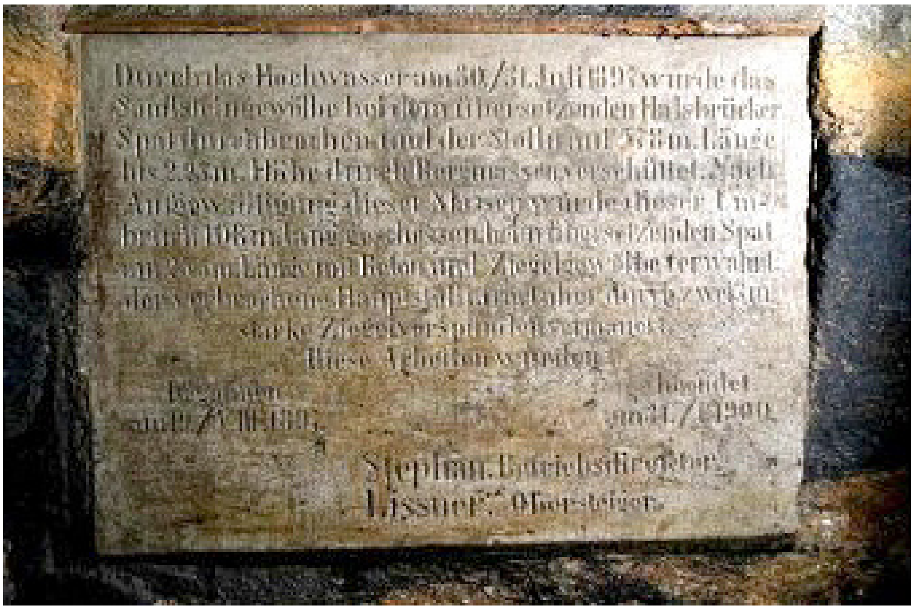


Fig. 15: Memorial tablet commemorating the mine blow due to flood in 1897 on the German side of the Krušné hory / Erzgebirge Mts.

Fig. 16: Memorial to flood victims in the village of Dolní Maršov. On the tablet we read: „At this place the flood took down the house number 45 on 29-30 July 1897 and 17 persons lost their lives“ (Photo: P. Klapka)

River for the town of Liberec and provincial districts of Jablonec nad Nisou, Chrastava and Frýdlant“ (Žák 2006). The statutory meeting took place in January 1900 and discussed already a proposal for the construction of six dams in the region of Jizerské hory Mts. The project was unique in the Hapsburg monarchy and was grounded on the experience of West Europe. The main author was Otto Intze, a prominent German expert in the construction of dams and professor at the Aachen Technical University. Dam reservoirs Harcov, Bedřichov, Fojtka, Mlýnice, Mšeno, Souš and Bílá Desná were later gradually built on streams in the Jizerské hory Mts. in 1902-1915.

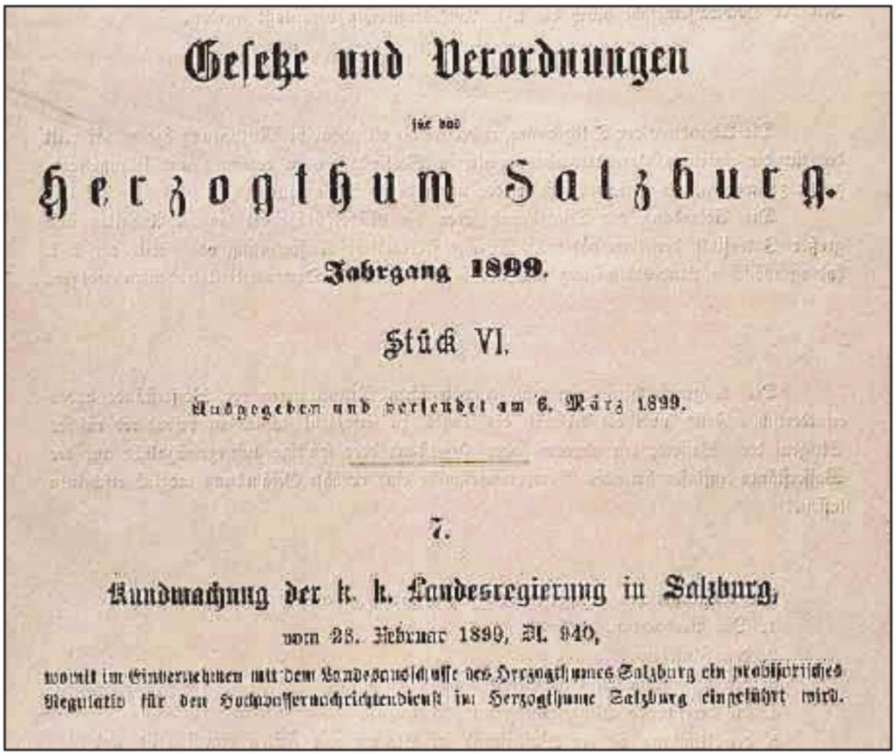
In Saxony where 19 persons were killed in the Weisser R. basin during the flood of 1897, valley dam reservoirs Malter, Klingenberg and Lehnmühle were built in 1908-1931 to prevent the future flood damage.

As to the Krkonoše Mts., the flood of modern times in July 1997 could have had much more severe consequences in mountains and piedmont than the disaster in 1897. Our contemporaries were protected from the new calamity by a sophisticated system of dams, dam reservoirs, regulations and sluices constructed at the beginning of the 20th century for a lot of money from the then Czech provincial authorities in Austria-Hungary. For example, regulation works carried out after the flood in 1897 on streams in the watershed of Malé Labe R. invite deserved attention by their thoroughness. They have resisted the elements for nearly a century now and apparently, thanks to them the flood losses in 1997 were not big. The Provincial Committee in Prague was responsible for the management of the regulations. The works split into several stages and continued even during World War I and after the constitution of the Czechoslovak Republic in 1918.

In Silesia, the flood of 1897 was a similar impetus to build flood-protection works. One of the largest ones was the dam reservoir in Pilchowice on the Bober River near the town of Jelenia Góra. As in the case of flood-control works in Czechia and Saxony, its project architect was professor Otto Intze from Aachen. The work was built in 1906-1912 and German Emperor Wilhelm attended its putting into operation.

The flood and the immense damage suffered in Silesia were responded to by the then legislation. The Act of 16 September 1899 on flood-control measures on the mountain sections of left-bank Odra (Oder) River tributaries initiated radical efforts for flood prevention. Another Act of Law adopted as early as in the following year on 3 July 1900 concerned means for the elimination of flood risks in the Silesian province. The Act of 12 August 1905 on means to regulate the runoff of high water and to erect dams on the upper and middle reaches of the Odra (Oder) River completed the efforts (Wawoczny 1998).

The summer floods of 1897 affected the Danube R. basin, too, and local authorities had to respond to incurred damages and to take measures. In Salzburg for example, they were impetus for the issue of flood instructions (Fig. 17). In Bohemia, the flood instructions remained in effect that were issued already in 1891 after the disastrous flood in September 1890.



Geſetze und Verordnungen
für das
Herzogthum Salzburg.
Jahrgang 1899.
Stück VI.
Ausgegeben und verſendet am 6. März 1899.

7.

Kundmachung der k. k. Landesregierung in Salzburg,
vom 23. Februar 1899, Z. 940,
womit im Einvernehmen mit dem Landesausſchuſſe des Herzogthumes Salzburg ein proviſoriſches Regulativ für den Hochwaſſernachrichtendienſt im Herzogthume Salzburg eingeführt wird.

Fig. 17: Front page of the instruction „Temporary regulation for high water alarm service in the duchy of Salzburg" issued on 23 February 1899 (Wiesenegger 2002)

6. Conclusion

The summer floods of 1897 represent a typical example of the hydrometeorological extreme reaching across the state borders because they affected a number of European countries. Due to the fact, that the culmination of water streams occurred largely at night, the high water took a toll of at least 167 human lives as documented by us so far. Material losses on dwelling houses, industrial premises, bridges, roads, farmland and crops were immeasurable and thousands of people lost roof over their heads. A beneficial consequence of this extreme flood event was however the change in the perception of flood-protection measures. This extreme flood event closed the 19th century, which is denoted today often as a „century of big floods".

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SURFACE ATMOSPHERE LAYER TEMPERATURE REGIME (CASE STUDY OF THE NATURE PARK BYSTŘICE RIVER VALLEY, THE NÍZKÝ JESENÍK HIGHLAND, CZECH REPUBLIC)

Miroslav VYSOUDIL

Abstract

The temperature regime in the surface atmosphere layer in the Bystřice River Valley Natural Park, in the central part of Nízký Jeseník Highlands, Czech Republic, is examined in this paper. Time series from 7 functional automatic meteorological stations were analyzed from May to August, 2006. In an effort to capture active surface effects in the greatest possible detail, air temperatures at a height of 1 m at intervals of 30´were measured. Only those time series from radiation days represented by days with anti-cyclonic weather situations were analysed. The study covered analysis of the average monthly temperatures, extreme daily and monthly temperatures, and temperature amplitudes with respect to altitude, local specifics of station elevations and the predominant character of the active surface in their surroundings. At selected stations, attention was focused on the rate and intensity of surface atmosphere layer warming in July, at 6:00 – 14:00 CEST. During the same time period, temperature inversions were analyzed with respect of their intensity and duration. Results of the analysis demonstrated considerable temporal and spatial differences in the temperature régime at the level of topoclimate. It was concluded that absolute altitude, great elevation differences between the stations and variations in their aspect, along with local geomorphological conditions, represent key factors in the temperature régime dissimilarities or in the existence of pronounced differences in topoclimates in the Nature Park territory.

Shrnutí

Režim teploty vzduchu v přízemní vrstvě atmosféry: případová studie Přírodní park Údolí Bystřice (Česká republika)

Příspěvek analyzuje režim teploty v přízemní vrstvě atmosféry na území přírodního parku (PP) Bystřice (střední část Nízkého Jeseníku, ČR). Analyzovány byly teplotní řady ze 7 účelově zřízených automatických stanic v období květen – srpen 2006. Ve snaze maximálně podchytit vlivy aktivního povrchu byla teplota měřena ve výšce 1 m v 30´ intervalech. Rozboru byly podrobeny pouze časové řady z radiačních dnů, reprezentované dny s anticyklonálním počasím. Vlastní studium zahrnovalo rozbor chodu průměrných měsíčních teplot, extrémních denních teplot, teplotních amplitud s ohledem na nadmořskou výšku, místní specifika polohy stanic a převládající charakter aktivního povrchu v jejich okolí. Na vybraných stanicích byla věnována pozornost míře a intenzitě prohřívání přízemní vrstvy atmosféry v měsíci červenci v čase 6 – 14 h SELČ. V tomto období byly též analyzovány teplotní inverze z hlediska jejich intenzity a délky trvání. Výsledky analýzy prokázaly značné časoprostorové rozdíly v režimu teploty na úrovni topoklimatu. Bylo shledáno, že absolutní nadmořská výška, velké výškové rozdíly mezi stanicemi, rozdíly v jejich orientaci spolu s místními geomorfologickými podmínkami představují klíčové faktory existence výrazných rozdílů topoklimatu na území PP, zejména pak režimu teploty přízemní vrstvy atmosféry.

Keywords: *air temperature regime, anti-cyclonic weather situation, surface atmosphere layer, temperature inversion, warming, Bystřice River Valley Nature Park (NP), Czech Republic*

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1. Introduction

In-depth study of topoclimate is one of the main tasks for the contemporary practical climatology. Particularly expressive differences of topoclimate we can see in areas with significant differences in elevation, non-uniform active surface, and human activities. Due to the high probability of anthropogenic impact on the local climate, the goal of topoclimatic research is to describe its contemporary pattern, and to try to establish conditions for sustainable topoclimate. This is also the case of topoclimate studies in the central part of the 'Nízký Jeseník Highland' (Czech Republic) where the 'Nature Park Bystřice River Valley' (thereinafter NP) is situated

(Fig. 1 – see cover p. 3). The Bystřice River creates there a deep valley of largely N-S aspect (Fig. 2).

Therefore, we can expect very intensive thermodynamic processes in the surface atmosphere layer in the NP, namely on days with radiation weather. Because of the mentioned processes, there is a high probability of local climatic effects and thus considerable topoclimate diversity. Depending on the location of the place, there will be most likely great local air temperature differences, occurrence of distinct temperature inversions and in some cases local circulation displays.

In this paper there are presented results of an analysis into the time-spatial regime of air temperature and some elevation-dependent temperature characteristics in the surface atmosphere layer with respect to their affection by georelief character. The nature of the predominant active surface in meteorological stations' surroundings was taken into account, too. With respect to the area's individuality, intensity of the surface atmosphere layer warming was studied in detail during days with the prevailing radiation (anticyclonic) weather character. Attention was given also to the occurrence of inversion situations.

2. Localization of the case studies

2.1 Functional network

Temperature time series were obtained from topoclimatic measurements in a special-purpose functional network of meteorological stations installed in the experimental area from April to October 2006. The temperature data were recorded 1 m above the active surface in order to capture in most details the effect of active surface on the air temperature regime in the surface atmosphere layer. The interval of temperature measurements was 30´, all data in the below text relating to time are in Central European Summer Time (UTC+2). The functional network is described in detail in Vysoudil, Navrátil (2006). Abbreviated names of the meteorological stations used in the below text are as follows (Tab. 1).

Active surface in the surroundings of all stations was represented by low vegetation. Close to the stations DET, POH, MB and RAD full-size trees were situated. Near surroundings of the LIH and DD stations was without grown-up vegetation. In the immediate environment of the LIH station there were fishponds and not far from the DD and LIH stations there is the Bystřice River. Unshaded and located on the SE slope was the POSL station. The POH station's aspect was expressively S to SW.

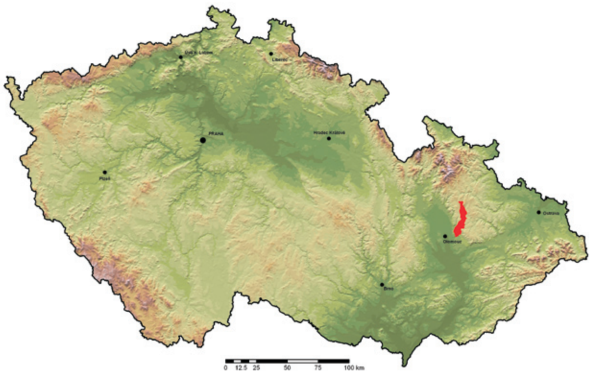

Fig. 2: Area under study

2.2. Input database

The records from days when the weather could be considered of radiation character were used for the analysis. The weather of those days was affected by anticyclonic situations. This autochthonous weather type is generally characterized by higher values of global radiation due to lower cloudiness, minimum rainfalls, and often by low wind velocities. Such meteorological conditions are main agents in the formation of distinctive local climate.

According to the 'Catalogue of weather situations' (CHMI, 2007), the Czech territory was influenced by anticyclonic weather situation for 90 days in the period from April – October 2006. Because of interrupted measurements, the number of records was not equal at all stations. Measurements from 7 stations contained records for 551 days, i.e. 78.7% of the total amount of theoretically possible ones. Maximum numbers of days (90) with uninterrupted measurements at the time of aticyclonic weather were available only at MB, RAD and DD stations. Complete time series (123 days) for all stations were available only for the period May – August. During this period 50 days with anticyclonic weather

Station/Abbreviation	Latitude	Longitude	Level m a.s.l.	Terrain location/Aspect
Dětřichov nad Bystřicí/DET	N 49° 49.4‘	E 17° 23.8´	608	peak site/south
Pohořany/POH	N 49° 40.3‘	E 17° 22.6´	561	peak site/south, SW
Moravský Beroun/MB	N 49° 47.3´	E 17° 26.4´	545	peak site/SE
Domašov n. B. – líheň/LIH	N 49° 43.3´	E 17° 27.0´	458	valley bottom/no aspect
Radíkov/RAD	N 49° 38.5´	E 17° 22.1´	425	peak site/no aspect (S)
Posluchov/POSL	N 49° 38.0‘	E 17° 23.6´	391	slope site/SE, east
Hlubočky – domov důchodců/DD	N 49° 39.6´	E 17° 24.6´	307	valley bottom/no aspect

Tab.1: Basic geographical characteristics of stations in the NP Bystřice River Valley

were recorded; therefore, the presented analyses cover those months.

The number of days with the occurrence of anticyclonic weather situation was as follows: A (8), Ap1 (2), Ap2 (4), Ap3 (4), SEa (6), SWa (2), Ea (2), NEa (9), and Wal (13).

The rate of surface atmosphere layer warming and the occurrence of temperature inversions were analyzed only in the month of July. This was because of all treated days the frequency of anticyclonic weather situations was highest in July (25 days). The representation of anticyclonic weather situations was as follows: A (6), Wal (11), NEa (5) and SEa (3).

Main subject of the study is the air temperature regime; therefore, the influence of selected anticyclonic weather situations on temperature courses is described. For instance, under the influence of weather situation 'A', radiation effects combined with orography can cause frequent long-term temperature inversions due to low cloudiness and weak flowing. The radiation weather regime may also occur in the 'NEa' situation. The minimum and maximum values may exhibit considerable variances between lowlands and mountain areas. In the 'SEa' situation, temperature differences can be observed between stations in lowlands and those in mountain elevations with average daily temperature maximums possibly showing inversion. In case of the 'Wal' situation, convection precipitation may occur, fixed to cold fronts, which may wipe-off the effect of radiation weather (Křivancová, Vavruška, 1997).

2.3. Temperature time series processing

The basic processing of input temperature series and the calculation of climatic characteristics for the purposes of intended analyses were made at time intervals of the V-VIII period, month, day or 30´. Subsequently, their links to local geographical conditions were established, possibly a context with the individual types of anticyclonic situations. Basic characteristics were:

- average daily temperature T_{d_avg} (calculated from the 30´ records)
- maximum daily air temperature T_{d_max} and the time of its occurrence t_{max}
- average monthly air temperature T_{m_avg}
- average maximum monthly air temperature $T_{m\_max\_avg}$
- minimum daily air temperature T_{d_min} and the time of its occurrence t_{min}
- average minimum monthly air temperature $T_{m\_min\_avg}$
- average monthly air temperature amplitude A_{m_avg}
- maximum daily air temperature amplitude A_{d_max}.
- average maximum monthly air temperature amplitude $A_{m\_max\_avg}$.

Dependence of the respective air temperature characteristics T_{d_max}, $T_{m\_max\_avg}$, T_{m_avg}, T_{d_min}, $T_{m\_min\_avg}$, A_{m_avg}, A_{d_max} on the altitude was determined by calculating correlation coefficients. Dependence on the elevation was calculated also for the occurrence time of the daily maximum t_{max} (minimum t_{min}) air temperature. The detected measure of dependence was related to the local environment conditions of individual stations. Due to the low number of stations (7), it was necessary to consider the results from the statistical point of view as preliminary information. A possible statistical significance was established for the (n-2) degrees of freedom, i.e. 5 on a level of significance p=0.05, resp. p=0.01 (Nosek, 1972). On the other hand, even these results provided sufficient information about the diversity of local climatic conditions in the area under study.

The days with the radiation weather in the month of July were selected **to establish the rate and intensity** of the surface atmosphere layer warming during the early morning and noon hours. As mentioned above, the number of days with the anticyclonic weather in July 2006 was 25. From 2 – 27 July 2006, these days followed continuously and thus, in addition to the georelief and active surface influences, a specific impact of individual weather situations on the surface atmosphere warming could show, as well.

The rate and intensity of warming were established between 6:00 – 14:00 o'clock CEST and during this period, the 30´ temperature differences were gradually calculated. The first value was to express the difference ($T_{6:30}$ – $T_{6:00}$), the second one ($T_{7:00}$ – $T_{6:30}$), etc. In the next step, a total value of the temperature increase and its maximum values in 30´ intervals, including the occurrence times were established. The interval values were used to characterize the intensity of warming in relation to local specifics given by the geographical location of the respective stations. The concerned stations were in the MB – LIH – DD profile.

The 30´ records from July 2006 were used as well to characterize the occurrence of **local radiation** temperature inversions. The inversions were identified in a profile of the stations MB (545 m a.s.l.) – LIH (458 m a.s.l.) – DD (307 m a.s.l.). Total elevation difference between the MB – DD stations is 238 m. Total elevation difference between the MB and LIH stations is only 87 m but the stations feature entirely different local conditions. Elevation difference between the LIH and DD stations was 151 m. With regard to the location of remaining stations, the selected profile appeared to be most representative for the study of temperature inversions.

Potential inversion was considered a situation, when the temperature difference at 6:00 a.m. CEST between of station couples MB- LIH, MB – DD and LIH – DD was positive. If the temperature difference was positive at least in three consecutive 30´ intervals, i.e. 1.5 hour, the situation was deemed inversion. The situations established in this way were in the next step assessed in terms of duration and time of the occurrence, and also for the magnitude of temperature differences in the 30´ intervals. It can be assumed that most of inversions in the Bystřice R. Valley NP are of radiation character. This was the reason why their occurrence, temperature and time characteristics were explored only from 6.00-14.00 o'clock CEST when they cease to exist in most cases. The inversions were evaluated by their duration. Inversion shorter than 2 hours was considered to be a "short-term inversion", inversion lasting from 2 to 4 hours a "medium-term inversion" and >4 hours a "long-term inversion". As to the magnitude of temperature differences, the inversions were evaluated as "mild" (0.1–3.0°C), "of medium intensity" (3.1–6.0°C), "intense" (6.1–9.0°C), and "massive" (9.1–12.0°C), see Petrovič (1960). Maximum temperature differences among the stations MB, LIH and DD were established as well.

Tables and graphs in the text are to enhance the information value of the paper, to graphically present and complete the established results.

3. Results

3.1 Air temperature

Average monthly air temperature T_{m_avg}

Average monthly air temperatures at stations in the NP were calculated from average daily air temperatures. The average daily temperatures originated from 30´ values. The characteristics of air temperature and their amplitudes are shown in Tab. 2.

Average monthly air temperatures in the period V–VIII differ from the overall average (17.6 °C) quite individually, and reflect different local environmental condition of the stations and their environment. The low average value at the DET and MB stations relates to high altitude. The low average temperature value at the LIH station is affected by location at the bottom of the Bystřice River Valley and by the proximity of a fish-hatchery. The above-average temperature values at the higher situated POH station reflects its S-SW aspect and a similar favourable aspect we can see in another summit station of RAD. The above-average temperature values at the POSL station originate from the E-SE aspect of the surrounding georelief.

The comparison of average monthly temperatures points to a considerable temperature increase between May and June (5.5°C), even though the number of days with the radiation weather was equal. The subsequent increase from June to July (3.2 °C) corresponds with the usual growth of average monthly temperatures, which is followed by the decrease from July to August (3.4°C). The effect of the anticyclonic weather on the higher level of average monthly temperatures manifested most expressively in the month of July 25 days of 31 possible ones).

The amplitude of average air temperature in the period V-VIII was 2.0°C. Values of individual months fluctuated from 3.0°C to 4.4°C. In respect of individual months, the greatest diference in amplitudes was found between the DET and RAD stations, resp. POSL. The values concerned were never between the highest-lowest situated stations or between the valley-summit situated stations. Main reason for the differences was the southern aspect of the RAD station, or the eastern aspect of the POSL station. The difference in amplitude between the DET and RAD stations was 4.4°C in July, and 3.6°C in June.

Maximum daily air temperature and time of its occurrence

In studying the topoclimate, extreme daily air temperatures and the time of their occurrence represent characteristics that are markedly affected by local georelief and its active surface forms.

Station	m a.s.l.	V	VI	VII	VIII	V-VIII
DET	608	*10.8*	*16.2*	*19.1*	*16.2*	*15.6*
POH	561	13.4	18.8	22.3	17.7	18.1
MB	545	11.8	17.5	20.1	17.7	16.8
LIH	458	11.4	16.7	19.6	17.1	16.2
RAD	425	**13.9**	**19.8**	**23.5**	19.0	**19.1**
POSL	391	**13.9**	19.4	23.0	**19.2**	18.9
DD	307	13.5	18.8	22.3	18.8	18.4
T_{m_avg}	-	12.7	18.2	21.4	18.0	17.6
A_{m_avg}	-	3.1	3.6	4.4	3.0	2.0

Tab. 2: Average monthly air temperature T_{m_avg} (°C) and its amplitude A_{m_avg} (°C) measured at the stations of Bystřice R. Valley NP in V–VIII 2006
abbreviations see Tab. 1

Absolute daily maximum temperatures were fixed to the lowest-situated DD station except for the month of May (POH). During the months of June and August, the same values as at DD were recorded at the RAD station. Main reason to the highest values measured at the DD station is the lowest elevation. The effect of higher elevation on the level of maximum daily temperature was in the case of RAD and POH stations smoothed by the favourable exposure to southern quadrant.

The combination of altitude and active surface type at the MB station was likely responsible for the fact that with an exception of August, absolute maximum temperature values were permanently the lowest. In the month of August, the lowest maximum temperature (26.0°C) was recorded at the POH station. Levels of the lowest daily maximums at the LIH valley station (26.6°C) differed only minimally from values at MB (26.1°C) and POH (26.0°C).

The average amplitude of daily maximum temperature was 2.7°C in the period from V–VIII. Values during the observed months were as a whole equable, too (from 2.4°C to 3.0°C). In May, the greatest difference in amplitude values was observed between the POH and MB stations, resp. LIH. Main reason was a higher elevation and better ventilation at the MB station (lower amplitude) and the valley position of the LIH station (higher amplitude). In June, July and August, the largest amplitude difference was between the stations RAD and DD, resp. MB; between the stations DD and MB; and between RAD, resp. POSL and POH stations, respectively (see Tab. 3).

Average time of the maximum daily temperature occurrence fluctuated in the respective months between 13.57 and 14.30 o'clock. Due to the potentially longest sunshine resp. the Sun height above the horizon at the time of culmination, it was earliest in June (13.57 o'clock) and latest in July (14.30 o'clock).

The time of the absolute maximum daily air temperature occurrence at all stations and in all months was characterized by shift to afternoon hours. The maximum was not reached before 13:00 p.m. The earliest occurrence of daily air temperature maximum in May showed the highest located station DET, in June the MB station, in July the POH station, and in August the DD station. In principle, there was practically no significant difference between the respective months in the latest occurrence time because it was at all times falling into the interval between 15:00 – 16:00 o'clock. The latest occurrence time was recorded at POH and POSL in May (3.50 p.m.), in June at RAD (3 p.m.), in July at MB and POSL (3.00 p.m.) and in August at POH (4 p.m.).

The linkage of absolute daily maximum temperatures to anticyclonic weather situation varied from month to month. In May, June and August, it was in all cases one situation: (May – Ap3, June – Wal, August – NEa). Only in July, the daily maximum temperature at individual stations related to different weather situations (DET, RAD, POSL – A, POH, MB, LIH, DD – Wal). The findings correspond to the character of temperature regime in summer months under the above mentioned weather situations.

Average maximum monthly air temperature

Knowledge of the temperature course in the ground atmosphere layer completes the data on average maximum monthly temperatures.

Altitude also showed its influence on the level of average maximum monthly air temperatures. The highest average monthly maximum was reached at the station DD (26.1°C). Favourable exposure of the georelief surroundings affected the temperature values at the stations RAD (25.8°C) and POH (25.1°C). High elevation of the DET station caused the average maximum here to be the lowest, as was the case at the nearby station MB. When looking at the individual months, the average monthly maximum is linked to POH (May), RAD (June), DD (July, August). It is clear that the values were influenced by the low elevation as well as by the S and E aspect. The lowest average monthly maximums relate to the DET station (except for August).

Station	**m a.s.l.**	**V**			**VI**			**VII**			**VIII**			**V-VIII**
		T_{d_max}	t_{max}	ws	T_{d_max}	t_{max}	ws	T_{d_max}	t_{max}	ws	T_{d_max}	t_{max}	ws	$T_{d\_max\_avg}$
DET	608	22.4	13.00	Ap3	28.9	13.50	Wal	33.9	14.00	A	27.5	14.00	SWa	28.3
POH	561	**24.7**	**15.50**	Ap3	*27.6*	13.50	Wal	35.0	13.50	Wal	*26.0*	**16.00**	SWa	28.9
MB	545	*22.2*	13.50	Ap3	27.8	11.50	Wal	*33.5*	**15.00**	Wal	26.1	13.50	SWa	*27.6*
LIH	458	*22.2*	14.50	Ap3	29.9	12.50	Wal	33.6	14.30	Wal	26.6	14.00	SWa	27.8
RAD	425	23.6	13.00	Ap3	29.1	**15.00**	Wal	35.4	14.30	**A**	**29.0**	15.00	SWa	29.9
POSL	391	23.1	**15.50**	Ap3	**30.3**	14.50	Wal	35.7	**15.00**	A	27.9	14.50	SWa	29.1
DD	307	24.6	14.50	Ap3	28.8	14.50	Wal	**35.9**	14.00	Wal	**29.0**	13.00	SWa	**30.3**
$T_{d\_max\_avg}$	-	**23.3**	14.21	**-**	**28.9**	13.57	**-**	**2.4**	14.30	**-**	**3.0**	14.29	-	**28.8**
A_{d_max}	-	2.5	2.50	-	2.7	2.0	-	T_{d_max}	1.5	-	T_{d_max}	3.0	-	**2.7**

Tab. 3: Maximum daily air temperature T_{d_max} (°C), time of its occurrence t_{max} (hr), average maximum daily temperature $T_{d\_max\_avg}$ (°C), and amplitude of maximum daily air temperature A_{d_max} (°C) at stations in the Bystřice R. Valley NP in V–VIII 2006 (ws – weather situation)
abbreviations see Tab. 1

Same as the absolute daily maximum temperatures, their average values, too, show the most marked increase between the months May and June (5.6°C).

The average maximum air temperature amplitude in the period V-VIII was 2.5° C (Tab. 4). Temperature amplitudes during individual months were falling into an interval from 2.5°C (June) – 3.2°C (May). The maximum difference between amplitudes was observed in May between the highest POH station and the relatively high-situated DET station with southern aspect and good ventilation (3.2°C). The greatest amplitude difference in June, July and August was found between RAD and DET, DD and DET, and DD and POH, respectively.

Station	m a.s.l.	V	VI	VII	VIII	V-VIII
DET	608	*18.3*	*24.0*	*28.0*	24.0	*23.6*
POH	561	**21.5**	25.8	29.7	*23.4*	25.1
MB	545	18.6	24.7	28.5	24.0	24.0
LIH	458	19.3	25.1	29.0	24.5	24.5
RAD	425	20.3	**26.5**	30.4	25.8	25.8
POSL	391	19.9	25.4	30.1	25.1	25.1
DD	307	20.9	26.4	**30.9**	**26.3**	**26.1**
T_{m_avg}	-	19.8	25.4	29.5	24.7	24.9
A_{m_avg}	-	3.2	2.5	2.9	2.9	2.5

Tab. 4: Average maximum monthly air temperature $T_{m\_max\_avg}$ (°C) and its amplitude $A_{m\_max\_avg}$ (°C) at stations in the Bystřice R. Valley NP in V–VIII 2006
abbreviations see Tab. 1

Minimun daily air temperature and time of its occurrence

Regarding the extreme location at the bottom of inversion valley, the occurrence of absolute minimum was justly expected at the LIH station. However, the **absolute daily minimum air temperature** was measured in all months at the highest-situated DET station. The findings demonstrate a conspicuous effect of elevation on their level. The finding was not affected even by the fact that except for May the summer months were analyzed. The **highest minimum** fell on June (RAD) although this station was by far not the lowest one. As was already emphasized in the case of maximum temperatures, the higher elevation was overweighed by the station's favourable aspect.

Significant variances exist in the values of absolute minimum air temperatures at the stations in individual months. The highest amplitude fell to June and the difference between the POH and DEP stations reached 6.9°C. A similar finding holds also in comparing values of LIH and RAD stations located at approximately same elevation, where the amplitude was 4.3°C (July). Topoclimate variances resulting from the location of the stations and from the character of the surrounding georelief are quite evident. In the case of MB and POH stations, both of similar elevation, the finding was analogous – the minimum temperature amplitude in June reached 6.5°C.

Times of the daily temperature minimum occurrence markedly differed. Nevertheless, it can be stated that they were fixed to late night or early morning hours. The only exception in this scheme were times in the month of June.

Of the individual anticyclonic weather situations accompanying the absolute daily minimum temperature occurrences, the NEa situation was represented most frequently, particularly in June and July, which corresponds with the weather character and namely with the temperature regime under that situation. Significant is participation of the Ap3 situation in May and the SWa situation in August.

Station	m a.s.l.	V			VI			VII			VIII			V-VIII
		T_{d_max}	t_{max}	ws	T_{d_max}	t_{max}	ws	T_{d_max}	t_{max}	ws	T_{d_max}	t_{max}	ws	$T_{d\_max\_avg}$
DET	608	**0.4**	4.00	Ap3	**1.6**	0.00	NEa	**5.5**	4.00	A	**5.3**	2.50	SWa	3.2
POH	561	5.5	5.00	SEa	***8.5***	5.00	NEa	9.7	6.50	NEa	11.0	6.00	Ap2	8.7
MB	545	1.5	1.50	Ap3	2.0	4.50	NEa	6.4	3.50	A	7.9	2.00	SWa	4.5
LIH	458	1.9	5.00	Ap3	2.7	4.00	NEa	7.0	3.00	NEa	8.9	5.00	SWa	5.1
RAD	425	***5.9***	4.00	Ap3	6.4	0.00	NEa	***11.3***	4.00	NEa	**11.8**	6.00	Ap2	8.9
POSL	391	5.6	5.50	SEa	6.1	0.00	NEa	10.0	4.50	NEa	10.8	5.00	SWa	8.1
DD	307	4.4	3.00	Ap3	5.4	3.00	NEa	7.9	4.00	NEa	11.3	1.00	SWa	7.3
$T_{d\_max\_avg}$	-	3.6	4.00	-	4.7	2.36	-	8.3	4.21	-	9.6	3.93	-	6.5
A_{d_max}	-	5.5		-	6.9		-	5.8		-	6.5		-	5.7

Tab. 5: Minimum daily air temperature T_{d_min} (°C) and the time of its occurrence t_{min} (hr), average minimum daily air temperature $T_{d\_max\_avg}$ (°C), and minimum daily air temperature amplitude A_{d_min} (°C), V–VIII 2006 (ws – weather situation)
abbreviations see Tab. 1

Average monthly minimum air temperature

The regime of average monthly minimum air temperatures at the stations corresponds very well with the level of absolute temperature minimums. The lowest average minimum was observed in all months at the DET station and at the highest-situated RAD station. Cardinals are differences between the RAD – LIH and MB – POH stations. The fact that the average air temperature minimum markedly differed at these stations located at similar elevations demonstrates how significant is the factor of local position of the stations, in addition to altitude (Tab. 6).

Station	m a.s.l.	V	VI	VII	VIII	V-VIII
DET	608	**2.6**	**7.5**	**10.1**	**8.4**	**7.2**
POH	561	7.8	13.4	16.5	12.6	12.6
MB	545	4.2	8.9	11.0	10.2	8.6
LIH	458	4.4	9.0	11.6	10.6	8.9
RAD	425	***8.1***	***13.6***	***17.2***	***13.3***	***13.1***
POSL	391	7.6	12.3	15.4	13.0	12.1
DD	307	6.5	11.6	14.6	12.5	11.3
T_{m_avg}	-	**5.9**	**10.9**	**13.8**	**11.5**	**10.5**
A_{m_avg}	-	**5.5**	**6.1**	**7.1**	**4.9**	**5.9**

Tab. 6: Average minimum monthly air temperature $T_{m\_min\_avg}$ (°C) and its amplitudes $A_{m\_min\_avg}$ (°C) at stations in the Bystřice R. Valley NP in V–VIII 2006
abbreviations see Tab. 1

The amplitude of average monthly minimum air temperatures in V-VIII was 5.9°C. In the respective months, the amplitudes of average minimum temperatures reached values ranging from 4.9°C (August) to 7.1°C (July). At all times, the values represented the difference between the DET and RAD stations, the main reason being altitude and position of the DET station.

3.2 Temperature amplitude

Temperature amplitude represents an important characteristic in studying the topoclimate. Its value reflects to a certain extent the nature and impacts of local georelief morphography and its active surface.

The temperature time series obtained during the observation in the functional network allowed to establish the average monthly amplitude of air temperature A_{m_avg} and its daily maximum A_{d_max} (°C) for each month (Tab. 7).

Average temperature amplitude for the entire period was 14.4 (°C). By contrast to theoretical expectations, the temperature amplitude was in general above-average at the DET station (16.4°C). This was apparently the effect of altitude combined with the convex shape of the georelief, just as in the case of the MB station. Conversely, in the case of the LIH station, the impact of its location at the bottom of markedly concave depression on the amplitude value was quite evident (15.6°C). The low average amplitude values at the POH and RAD stations are typical of summit sites.

By the respective months, the maximum amplitude value fell on July when the highest number of consecutive radiation days was recorded; thus, the impact of a radiation weather on the temperature amplitude level is clearly evident (Tab. 8).

If we abstract from the highest-situated DET station, the average monthly amplitude was at all times highest at the valley-situated LIH station. By contrast, the lowest amplitude was at all times recorded at one of the summit stations (RAD or POH). The fact fully corresponds with the thesis of Vojejkov law (Chromov, 1968, p. 130–132).

Station	m a.s.l.	V	VI	VII	VIII	V-VIII
DET	608	**15.7**	**16.4**	**17.9**	**15.6**	**16.4**
POH	561	13.8	13.8	*13.1*	*10.9*	12.9
MB	545	14.4	15.8	17.4	13.8	15.4
LIH	458	14.9	16.2	17.4	13.9	15.6
RAD	425	*12.1*	*12.9*	13.2	12.5	*12.7*
POSL	391	12.3	13.1	14.7	12.2	13.1
DD	307	14.4	14.7	16.3	13.8	14.8
A_{m_avg}	-	**13.9**	**14.7**	**15.7**	**13.2**	**14.4**

Tab. 7: Average monthly amplitude of air temperature A_{m_avg} (°C) at the stations in NP, V–VIII 2006
abbreviations see Tab. 1

Station	m a.s.l.	V		VI		VII		VIII		V-VIII
		A_{d_max}	ws	A_{d_max}	ws	A_{d_max}	ws	A_{d_max}	ws	A_{d_max}
DET	608	**22.0**	Ap3	**27.8**	Wal	**28.4**	A	**22.2**	SWa	**28.4**
POH	561	19.2	SEa	21.2	Wal	25.3	A	15.0	SWa	25.3
MB	545	20.7	Ap3	26.6	A	27.1	A	18.2	SWa	27.1
LIH	458	20.3	Ap3	26.2	A	26.6	A	17.7	SWa	26.6
RAD	425	17.7	Ap3	25.1	Wal	24.1	A	17.2	SWa	25.1
POSL	391	17.5	Ap3	23.5	Wal	25.7	A	17.1	SWa	25.7
DD	307	20.2	Ap3	26.1	A	28.0	A	17.7	SWa	28.0
A_{d_max}	-	22.0	-	27.8	-	28.4	-	22.2	-	28.4

Tab. 8: Maximum daily air temperature amplitude A_{d_max} (°C) at the stations in NP, V–VIII 2006 (ws – weather situation) abbreviations see Tab. 1

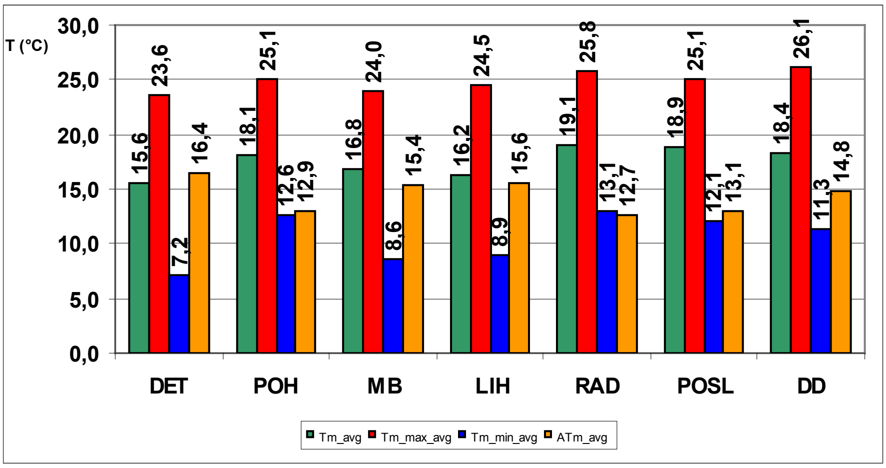

Fig. 3: Average monthly air temperature, average monthly maximum and minimum, and average monthly air temperature amplitude (°C) at stations in the NP, V–VIII 2006

The below-average values of air temperature amplitude at the POH, RAD and POSL stations satisfy a theoretical presumption about a temperature amplitude level with regard to its peak or slope location. The analysis of the temperature series at the valley station LIH confirmed the theoretical hypothesis of distinctively high amplitude. Higher amplitude at the station DET resulted mainly from the station's altitude, and possibly from the nearby high-grown vegetation that could weaken the wind flowing.

3.3 Effect of altitude on air temperature regime

Considerable geodiversity, namely the height differences between the individual stations led to the presumption of a more noticeable temperature regime correlation with the altitude. At the same time, it can be expected that these differences will depend on the rate and the intensity of the surface atmosphere layer warming.

To verify the authenticity, the correlation coefficients of the bellow dependence were computed for the period from V–VIII:

- average monthly air temperature – a. s.l. ($r_{Tm\_avg,z}$)
- average monthly maximum air temperature – a.s.l. ($r_{Tm\_max\_avg,z}$)
- daily maximum air temperature – a.s.l. ($r_{Td\_max,z}$)
- average monthly air temperature amplitude – a. s.l. ($r_{A\_m\_avg,z}$)
- average monthly minimum air temperature – a.s.l. ($r_{Tm\_min\_avg,z}$)
- daily minimum air temperature – a.s.l. ($r_{Td\_min,z}$)
- time of the occurrence of daily maximum (minimum) air temperature – a.s.l. $r_{tT\_d\_max\_z}$ ($r_{tT\_d\_min,z}$)

Statistical significance of correlation coefficients was tested as mentioned in Chapter 2.

In the case of correlation $T_{m\_avg,z}$, only in the month of August, due to the coefficient value -0.7917, the indirect dependence at the significance level p=0.01 can be considered proven and statistically significant.

Month	V	VI	VII	VIII	V-VIII
$r_{Tm\_avg,z}$	-0.63877	-0.58993	-0.60079	**-0.7917**	-0.65474
$r_{Tm\_max\_avg,z}$	-0.46116	-0.72438	**-0.85282**	**-0.90429**	**-0.82257**
$r_{Td\_max,z}$	-0.3996	-0.64593	**-0.71198**	**-0.70873**	**-0.70545**

Tab. 9: Correlation coefficients $r_{Tm\_avg,z}$, $r_{Tm\_max\_avg,z}$ and $r_{Td\_max,z}$ in the NP, V–VIII 2006

In the case of correlation $T_{m\_max\_avg,z}$ due to the coefficient values, statistically significant indirect dependence at the p=0.01 significance level can be considered proven for the months of July (-0.85282), May (-0.90429) and for the entire period V–VIII (-0.82257)(see Tab. 9).

The correlation between the daily maximum air temperature and the elevation $r_{Td\_max,z}$ appeared to be statistically significant in July and August, but only at a significance level of p=0.01. This was valid also for the entire period V–VIII.

Regression equations made it possible to establish the vertical temperature lapse rate ΔT (°C) of the average monthly air temperature T_{m_avg}, the average maximum monthly air temperature $T_{m\_max\_avg}$ and the daily maximum air temperature T_{d_max} (Tab. 10).

Generally, the vertical temperature lapse rates have the highest values in the case of average monthly temperatures T_{m_avg}. The values of the vertical temperature lapse rates of the average monthly temperature maximum (July, August) and the daily temperature maximum (August) can be considered as conspicuously higher. This predicates the fact that temperature maximums do not relate so closely to local geographical conditions.

Correlation coefficients $r_{Td\_min,z}$ and $r_{Tm\_min\_avg,z}$ proved to be statistically significant (level of significance p=0.01) only in August (Tab. 11).

Month	V	VI	VII	VIII	V-VIII
ΔT - T_{m_avg}	0.78	0.76	1.00	0.82	0.84
ΔT - $T_{m\_max\_avg}$	0.51	0.62	0.85	0.89	0.72
ΔT - T_{d_max}	0.40	0.71	0.69	0.85	0.66

Tab. 10: Vertical temperature lapse rate ΔT (°C) of the average monthly air temperature T_{m_avg}, average maximum monthly air temperature $T_{m\_max\_avg}$ and daily maximum air temperature T_{d_max} in the NP, V–VIII 2006

Month	V	VI	VII	VIII	V-VIII
$r_{Tm\_min\_avg,z}$	-0.52684	-0.46273	-0.47322	**-0.66983**	-0.52596
$r_{Td\_min,z}$	-0.54901	-0.33785	-0.43441	**-0.70529**	-0.52248

Tab. 11: Correlation coefficients $r_{Tm\_min\_avg,z}$ and $r_{Td\_min,z}$ in the NP, V–VIII 2006

The vertical temperature lapse rates in all observed months are expressively higher than in the case of the maximum air temperatures. They show a significant average monthly/absolute daily minimum temperatures regress with the altitude. The explanation for this occurrence is most likely the influence of the considerably broken concave georelief in the vicinity of the valley stations, and in some cases a relatively high altitude of some stations (Tab. 12).

In the case of correlation $A_{m\_avg,z}$ all computed coefficients for all observed months resulted in statistically insignificant relations (Tab. 13). The temperature amplitude vertical lapse rate in the NP achieved a value of 0.46°C. By contrast, actual values at the respective stations in the respective months did not imitate this fact; on the contrary, they confirmed a theoretical presumption about the relation between the temperature amplitude value and the georelief nature. It means higher temperature amplitude levels at the valley stations (LIH, DD) and lower at the peak stations (RAD, POH).

The results of the correlation coefficients calculation prove that an indirect correlation between the time of the daily maximum air temperature occurrence and the elevation is statistically insignificant (except for the month of August). They only signal a known piece of information that the higher the altitude, the later the time of the daily temperature maximum occurrence (Tab. 14).

Month	V	VI	VII	VIII	V-VIII
ΔT - $T_{m\_min\_avg}$	1.06	1.05	1.26	1.14	1.13
ΔT - T_{d_min}	1.17	0.83	0.87	1.45	1.11

Tab. 12: The temperature lapse rate ΔT (°C) of average monthly minimum air temperature $T_{m\_min\_avg}$ and minimum daily air temperature T_{d_min} in NP, V–VIII 2006

Month	V	VI	VII	VIII	V-VIII
$r_{A\_m\_avg,z}$	0.461559	0.452545	0.205498	0.177009	0.327527

Tab. 13: Correlation coefficients $r_{A\_m\_avg,z}$ in the NP, V–VIII 2006

Month	V	VI	VII	VIII	V-VIII
$rt_{T\_d\_max\_z}$	-0.2931	-0.5661	-0.19476	0.349158	-0.35789

Tab. 14: Correlation coefficients $r_{tT\_d\_max\_z}$ of the dependence of maximum daily temperature occurrence time on the altitude in the NP, V-VIII 2006 the NP, V–VIII 2006

The correlation between the daily minimum air temperature time occurrences and the altitude was from the statistical point of view insignificant. The coefficients only suggested the fact that the higher the altitude, the earlier the time of the daily temperature maximum occurrence (except for May - Tab. 15)

Month	**V**	**VI**	**VII**	**VIII**	**V-VIII**
$rt_{T\_d\_min,z}$	-0.07241	0.077768	0.227254	0.101901	0.096899

Tab. 15: Correlation coefficients $rt_{T\_d\_min,z}$ of the dependence of the daily minimum air temperature time occurrence on the altitude in the NP, V–VIII 2006

3.4 Surface atmosphere layer warming

Local differences in the warming regime of the surface layer atmosphere represent one of the most significant features of radiation weather consequences and thus, manifestation of topoclimate. The effect of site slope conditions and aspect directly reflect in the rate of warming. These factors determine the spatial variability of temperature regime at a level of local climate.

The rate of surface atmosphere layer warming was also studied in July 2006 when the days with an anticyclonic weather prevailed. The 30´ temperature records were analyzed from 6:00 – 14:00 o'clock. For the analysis, the stations in the profile MB (545 m a.s.l.) – LIH (458 m a.s.l.) – DD (307 m a.s.l.) were selected.

The overall highest average temperature increase rates were recorded at both valley stations LIH (15.1 °C) and DD (14.7 °C). The lower value at the MB station reflects its location (Tab. 16). The warming rate during the individual days and weather situations is evident in Figs. 4 – 6.

Station/m a.s.l.	**NEa**	**SEa**	**Wal**	**A**	T_{avg}
MB/545	8.3	11.7	12.1	16.8	**12.2**
LIH/458	12.9	14.5	13.8	19.1	**15.1**
DD/307	13.5	14.5	13.1	17.7	**14.7**
ΔT_{avg}	**11.6**	**13.6**	**13.0**	**17.7**	**14.0**

Tab. 16: The temperature growth ΔT (°C) from 6:00–14:00 at stations in the NP for the days with the anticyclonic weather situation, July 2006

With regard to the individual weather situations, the total warming rates were above-average in the early mornings and before mid-days at all station when the weather situations A and Wal prevailed. This effect was most conspicuous at the station LIH at the Bystřice River Valley bottom. The above-average values were caused by the multi-days action of the weather situation A.

Regardless of the altitude, the total temperature increase rate was uppermost at all stations when accompanied by the weather situation A. This occurrence was most evident at the LIH station (19.1°C) quite evidently due to its location at the inversion valley bottom. Conversely, in all cases the lowest temperature growth related to the MB station. The reason should be seen in its location open to SE, which allows for a gradual and uniform surface atmosphere warming from sunrise to sunset. The influence of the rest of weather situations, excluding the NEa, was more or less equal at all stations.

The absolute 30´ air temperature increase rates did not vary too much, neither by stations nor by weather situations. A maximum 30´ difference was recorded at the DD valley station in the NEa situation (6.4°C) and a minimum was recorded at the MB station (2.5ºC) in the same situation.

Station/m a.s.l.	**NEa**	**SEa**	**Wal**	**A**	ΔT_{max_avg}
MB 545	*2.5*	*3.9*	*3.4*	*3.9*	3.4
LIH 458	3.3	**4.6**	**4.0**	**4.0**	4.0
DD 307	**6.4**	4.4	3.9	*3.9*	**4.7**
ΔT_{max_avg}	4.1	4.3	3.8	3.9	4.0

Tab. 17: Maximum 30´air temperature increase rate ΔTmax (°C) from 6:00–14:00 at stations in the NP for the anticyclonic weather situation, July 2006

Warming rate for individual anticyclonic weather situations (selected days in July 2006)

Dissimilarity of the warming regime in the surface atmosphere layer and intensity of the individual anticyclonic weather situations in July 2006 at stations of the **MB – LIH – DD** profile were described using temperature records from 5 July 2006, 17 July 2006, 19 July 2006 and 23 July 2006.

Date	**ws**	**MB**	**LIH**	**DD**
5. July 2006	SEa	11.8	**15.0**	14.0
17. July 2006	NEa	8.9	**15.6**	**15.8**
19. July 2006	A	16.2	**21.2**	**21.2**
23. July 2006	Wal	**19.7**	19.4	19.2

Tab. 18: Air temperature increase rate ΔT (°C) from 6:00–14:00 at some stations under respective anticyclonic weather situations (ws), July 2006

On **5 July 2006**, the weather was affected by the **SEa** situation. The course of warming and its intensity corresponded very well with the local geographical conditions of individual stations. Thanks to its elevation, the MB station showed the lowest temperature increase rate (11.8ºC). On the other hand, thanks to its SE aspect and a minimal superelevation of the surrounding terrain, the temperature increase during the period of the most intensive growth (6:00 – 7:30 p. m.) was quite equable. The warming regime at the station **LIH** again relates to its already mentioned location. It manifests itself by both the later time of more intensive warming (8:00 a. m.) and by the higher maximum 30´ temperature

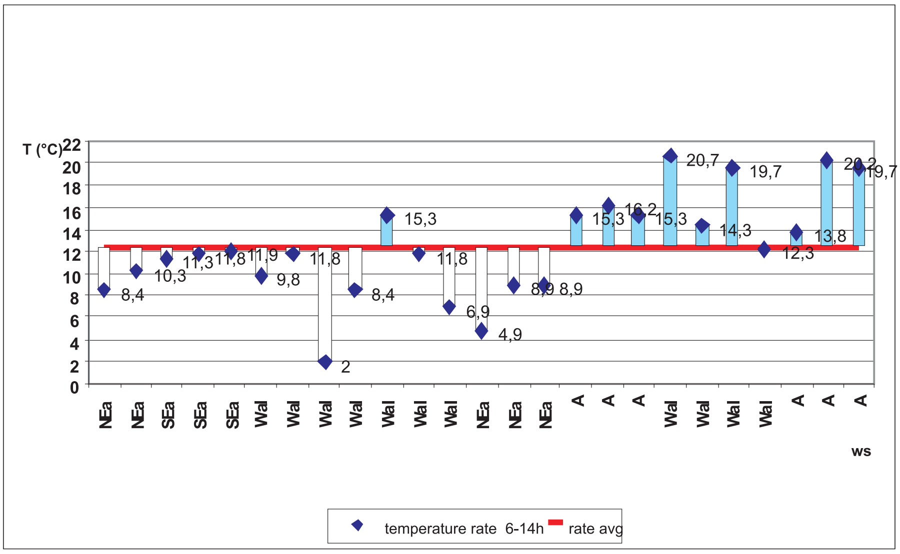

Fig. 4: Surface atmosphere layer warming (°C) at the MB station from 6:00–14:00, July 2006 (ws – weather situation)

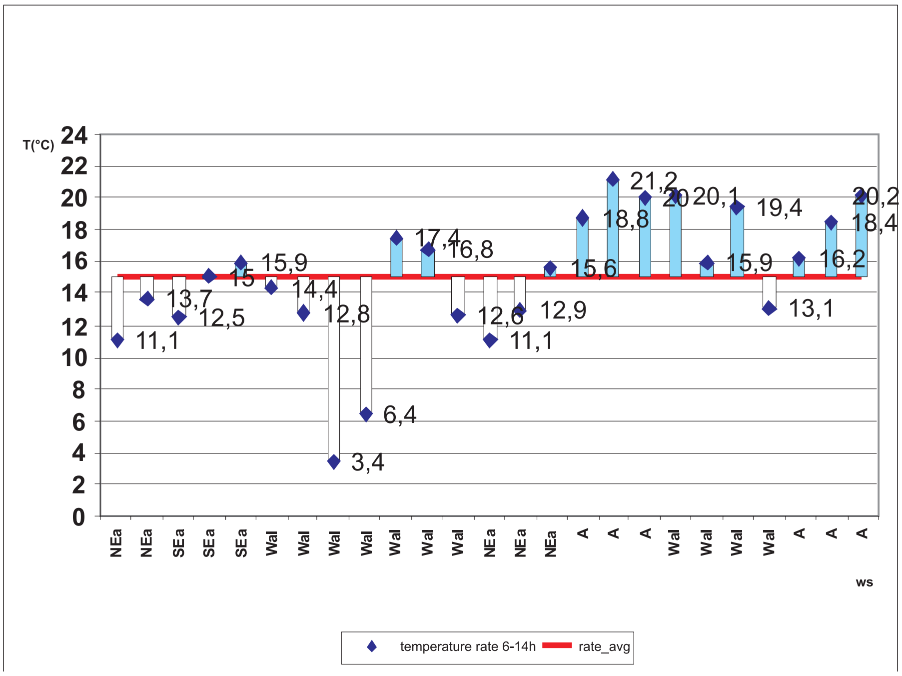

Fig. 5: Surface atmosphere layer warming (°C) at the LIH station from 6:00–14:00, July 2006 (ws – weather situation)

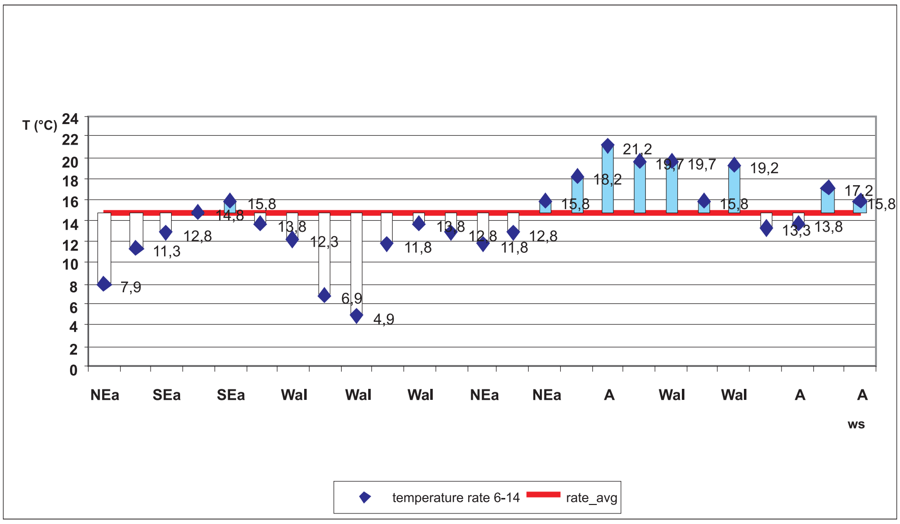

Fig. 6: Surface atmosphere layer warming (°C) at the DD station from 6:00–14:00, July 2006 (ws – weather situation)

difference (4.6°C) during the interval from 7:30 - 8:00 a. m. (Fig. 6). Local effects of the character of surface atmosphere layer warming at the **DD** station manifested in the case of the A situation less expressively than in the SEa situation. Maximum warming intensity (3.9°C) was observed from 7:30 to 8:00 a. m. (Fig. 7).

On **17 July**, the NP area was under the influence of **NEa** weather situation.

The overall air temperature increase rates at the stations LIH (15.6°C) and DD (15.8°C) did not significantly differ from each other. However, when compared to the value recorded at the MB station (8.9°C), they were nearly a double in size (Fig. 8). This might have resulted from better air ventilation possibilities at the MB station; thus, more favourable conditions developed for intensive turbulence, which suppressed the influence of the surface on the intensity of the surface atmosphere layer warming.

The intensity of warming in the weather situation NEa was equable at the station **MB** within the interval 6:00 – 14:00 but low when compared to the stations LIH and DD. A maximum rise during the 30´ intervals was only 2.5°C, while at the station **LIH**, the 30´ rates were very pronounced (maximum 3.3°C), particularly early in the morning. The temperature rise at the **DD** station was very vague; an extremely high increase (6.4°C) was recorded only from 7:00 – 7:30 o'clock.

The warming course and its intensity on **19 July** under the influence of weather situation A reflected well the influence of individual station sites.

The **MB** station -due to its elevation- had the lowest temperature increase rate. The warming course was most intensive and at the same time equable from 6:30 – 9:00 thanks to the SE exposure and the minimal superelevation. Within the 30´ intervals, the values varied from 3.4 to 2.0°C (Fig. 9). The nature of warming at the **LIH** station agrees with the terrain location at the bottom of the Bystřice River and with the massive superelevation of its near horizon. Georelief shades the station from the East, South and West, and the elevation difference between the station and the summit parts of the valley is about 150 meters. This results in the delayed start of more marked warming on the one hand (7:30 a. m.) and in a more intensive warming shown by higher 30´ temperature differences on the other

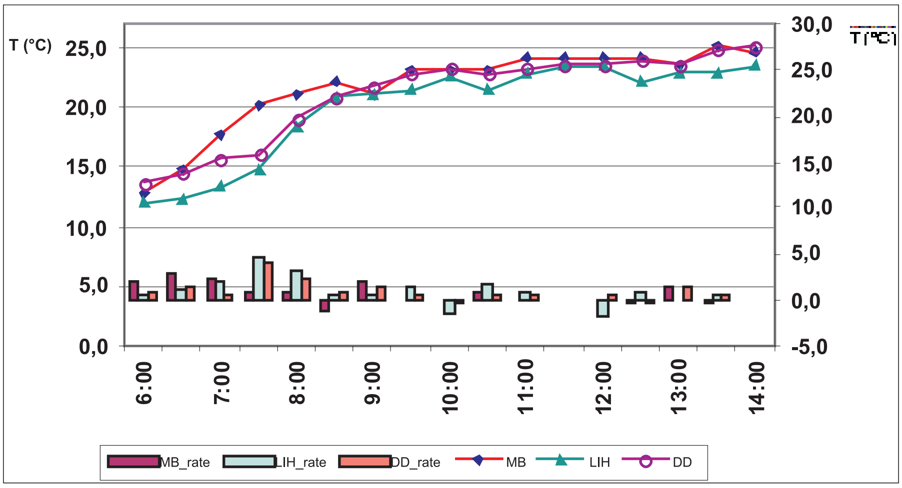

Fig. 7: Surface atmosphere layer warming (°C) at the MB, LIH and DD stations from 6:00–14:00 on 5 July 2006, weather situation SEa

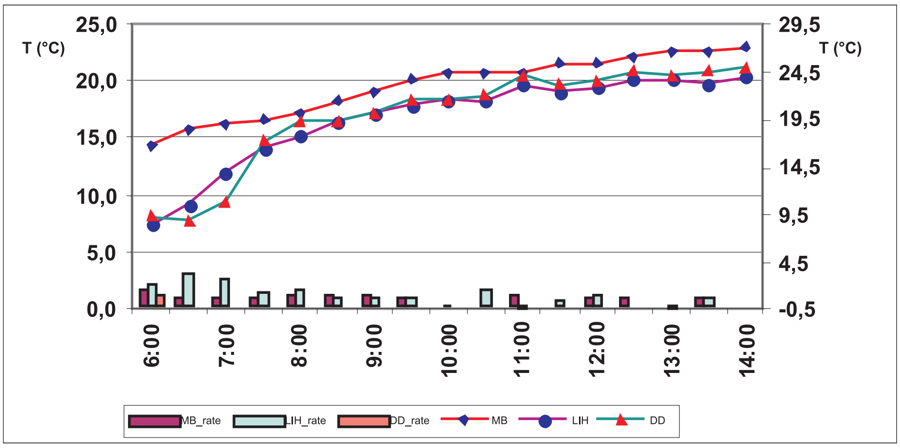

Fig. 8: Surface atmosphere layer warming (°C) at the MB, LIH and DD stations from 6:00 – 14:00, 17 July 2006, weather situation NEa

hand. The maximum difference was 4.0°C at 8:00 a.m. (Fig. 9). The lowermost located valley station **DD** (307 m a.s.l.) was situated at the bottom of the Bystřice River valley. Compared to the station LIH (458 m a.s.l.) the valley there is wider and open to the south. The vertical distance of the E and W slopes is around 200 meters. Therefore the maximum warming intensity (3.9°C) was shifted to later morning hours (9:00 a.m.).

On **23 July** 2006, the anticyclonic situation **Wal** was affecting the weather.

The **MB** station showed on this day a slightly highest warming (19.7°C) from 6:00 – 14:00. The temperature growth at the time of the most intensive warming (6:00 – 9:00) was quite even. The 30´ observed intervals showed discrepancy ranging from 2.0 to 3.0°C. The nature of warming at the **LIH** station was strongly shaped by local geographical conditions. Again, the intensive warming occurrence occurred later (8:30 – 9:00 and 9:00 – 9:30). These 30´ intervals had a temperature increase rate by 3.9°C and 3.2°C resp. At the lowest station **DD**, the value of the maximum warming reached 3.0°C and fell into the time interval from 8:30 – 9:00 a. m. (Fig. 10).

3.5 Temperature inversion

Radiation temperature inversions represent probably the most frequently occurring local climatic effects in areas with expressively vertically broken georelief, which represents the landscape type of Nízký Jeseník Highland including the Bystřice River Valley NP (Fig. 11 – see cover p. 3).

The incidence of local temperature inversions was examined in the MB – LIH – DD station profile in July 2006 on days under radiation weather. The stations in fact copy the longitudinal north-southern profile of the deeply incised Bystřice R. valley from its upper deeper spring section to the lower and wider reach.

Frequencies of temperature inversion occurrences on the above type of days and in separate couples of stations were as follows:
MB – LIH (difference in elevation 87 m): 25 events (100%)
MB – DD (difference in elevation 238 m): 22 events (88%)
LIH – DD (difference in elevation 151 m): 5 events (20%)

In accordance with a possible classification of temperature inversions by intensity (see Chapter 2), the most of

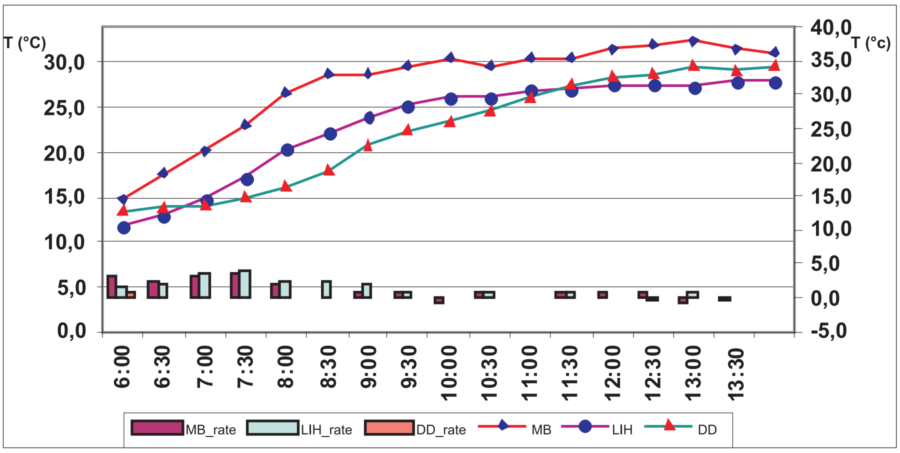

Fig. 9: Surface atmosphere layer warming (°C) at the stations MB, LIH and DD from 6:00 – 14:00 on 19 July 2006, weather situation A

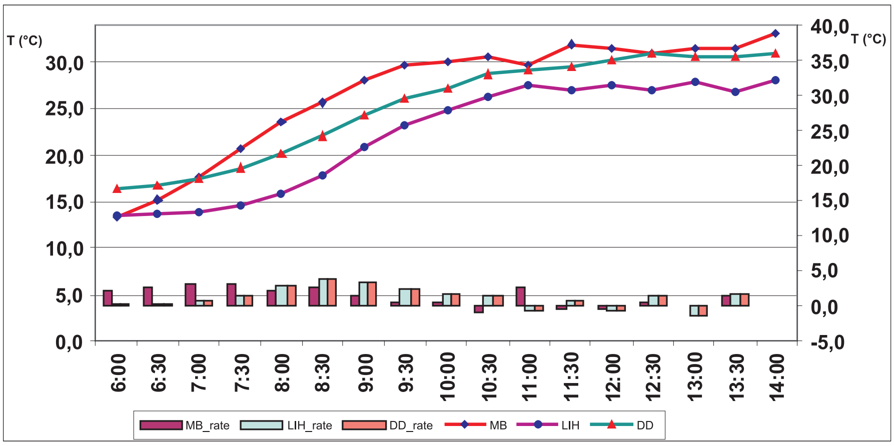

Fig10: Surface atmosphere layer warming (°C) at the stations MB, LIH and DD from 6:00 – 14:00 on 23 July 2006, weather situation Wal

Date/ws	5 July/SEa	17 July/NEa	19 July/A	23 July/Wal
MB				
ΔT_{6-14} difference 6-14 (°C)	11.8	8.9	16.2	19.7
ΔT_{max} max. rate (°C)	3.0	1.5	3.4	3.0
time interval (hr)	6:30–7:00	6:00–6:30	7:30–8:00	7:00–7:30, 7:30–8:00
LIH				
ΔT_{6-14} difference 6-14 (°C)	15.0	15.6	21.2	19.4
ΔT_{max} max. rate (°C)	4.6	3.3	4.0	3.9
time interval (hr)	7:30–8:00	6:30–7:00	7:30–8:00	8:30–9:00
DD				
ΔT_{6-14} difference 6-14 (°C)	14.8	15.8	21.2	19.2
ΔT_{max} max. rate (°C)	3.9	6.4	3.9	3.0
time interval (hr)	7:30–8:00	7:00–7:30	8:30–9:00	8:30–9:00

Tab. 19: Rate and intensity of surface atmosphere layer warming at stations in the NP (anticyclonic weather situation, selected days, July 2006)

inversions fell into the "mild" class. The "medium strong" inversions were less frequent and the "strong" inversions were only sporadic. Of all, the highest temperature difference (10.3°C) was recorded at 8:00 a.m. on 19 July (weather situation A) between the stations MB – DD. Maximum difference between the stations MB – LIH was 7.7°C (July 23rd, weather situation Wal) at 8:00 (8:30) a.m. In the case of stations LIH – DD, a maximum temperature difference reached 5.7°C (19 July, weather situation A) at 8:00 a.m.

Maximum duration of inversion relates to the stations MB – LIH; it occurred on 27 July under weather situation A, and the inversion persisted 6 hours (6:30 – 12:30). In the case of the stations MB – DD, the longest inversion occurred on 19 July and its duration was 5.5 hours (6:00 – 11:30, weather situation A). On the same day, the longest inversion occurred also between the stations LIH – DD (4.5 hours, from 7:00 to 11:30 a.m., weather situation A). Logically, a medium strong inversion was observed on that day also between the stations MB – LIH.

4. Discussion and conclusion

Just as expected, it was demonstrated that the air temperature regime and the values of the selected temperature characteristics were at individual stations in the NP distinctly different. Fundamentally, they reflect the local specific morphometry, relative and absolute elevation and the morphography (aspect, convexity and concavity) of the georelief.

Day	WS	Couples of stations/elevation difference (m)		
		MB-DD (545-307)=238	**MB-LIH (545-458)=87**	**LIH-DD (458-307)=151**
2.VII	NEa	-	1.5	2.0
3.VII	NEa	-	2.0	-
4.VII	SEa	3.0	4.0	-
5.VII	SEa	2.0	3.0	-
6.VII	SEa	2.5	2.5	-
7.VII	Wal	2.5	3.0	-
8.VII	Wal	2.5	3.5	-
9.VII	Wal	4.5	5.5	-
10.VII	Wal	3.5	4.0	-
11.VII	Wal	3.5	5.5	-
12.VII	Wal	2.0	4.5	-
13.VII	Wal	1.5	2.0	-
15.VII	NEa	1.0	1.5	-
16.VII	NEa	1.0	1.0	-
17.VII	NEa	1.5	2.0	1.0
18.VII	A	2.5	3.5	-
19.VII	A	**5.5**	4.5	**4.5**
20.VII	A	5.0	5.0	1.5
21.VII	Wal	2.0	5.0	-
22.VII	Wal	3.5	4.6	-
23.VII	Wal	2.0	5.0	-
24.VII	Wal	-	3.0	-
25.VII	A	1.5	4.5	2.0
26.VII	A	1.5	5.5	-
27.VII	A	1.5	**6.5**	-

Tab 20: Duration of temperature inversion (in hours) for selected weather situations in the profiles of stations MB-DD, MB-LIH and LIH-DD, July 2006

Day	WS	Profile		
		MB-DD (545-307)=238	MB-LIH (545-458)=87	LIH-DD (458-307)=151
2.VII	NEa	-	2.4	1.6
3.VII	NEa	-	3.8	-
4.VII	SEa	2.5	5.6	-
5.VII	SEa	4.4	6.0	-
6.VII	SEa	4.9	6.9	-
7.VII	Wal	3.0	5.3	-
8.VII	Wal	2.0	2.7	-
9.VII	Wal	3.0	6.2	-
10.VII	Wal	3.4	4.7	-
11.VII	Wal	3.9	6.7	-
12.VII	Wal	3.0	6.1	-
13.VII	Wal	3.4	5.9	-
15.VII	NEa	4.9	4.9	-
16.VII	NEa	2.0	2.8	-
17.VII	NEa	6.9	5.8	3.1
18.VII	A	3.0	4.6	-
19.VII	A	**10.3**	5.7	**5.7**
20.VII	A	9.4	5.7	5.3
21.VII	Wal	3.0	6.5	-
22.VII	Wal	5.4	6.6	-
23.VII	Wal	2.0	**7.7**	-
24.VII	Wal	-	1.8	-
25.VII	A	2.5	6.7	1.2
26.VII	A	1.5	6.5	-
27.VII	A	1.5	5.3	-

Tab. 21: Maximum air temperature difference (°C) for days with a temperature inversion in selected anticyclonic weather situations (ws) between station couples in the NP, July 2006

The temperature difference was computed for station couples for each 30‘ interval from 6:00–14:00.

Air temperature course can be generally classified as much individual at the respective stations. Principal influence is shown by elevation (DET), by the considerably deep valley position (LIH) and by the enclosed station aspect (POSL). It was demonstrated that in the case of the S and SE slope facing the effect of elevation could be reduced. Due to the relative altitude differences among the individual stations, a study was conducted of the mutual dependence of temperature characteristics (average monthly temperature, average monthly maximum/minimum temperatures, daily maximum/minimum temperatures, average monthly temperature amplitude, and times of daily maximum/minimum temperature) on the altitude. However, from a statistical point of view, in most of the cases the obtained results were insignificant even if certain indications of dependence were suggested. The statistically most significant elevation-related temperature decrease both for the average monthly maximum and for the daily maximum took place in the months of July and August and during the period V–VIII. While the time of daily altitude-dependent maximum temperatures was at individual stations slightly earlier, the time of the daily minimums arrived slightly later.

The overall character and intensity of temperature growth from 6–14 o’clock reflected local particularities of station locations. In practice, the lowest warming values occurred at the highest and well ventilated MB station except for July 23rd when the minimum rate (19.2°C) occurred at the valley station DD. As expected, maximum 30´ temperature rate reached the greatest level at the station LIH due to its position at the bottom of the inversion valley and due to the overshadowing by the surrounding georelief. Only on July 17th, a maximum 30´ rate was recorded at the station DD (6.4°C). The surface atmosphere warming rate between the MB and DD stations does not show any principal difference. As to the time of the day, the maximum 30´ growth rates are tied to the period between 6:30 – 9:00 o’clock. The interval 7:30 – 8:00 represents the most frequent time of maximum temperature rate distribution; it is principally valid regardless of station location or weather situation.

Due to the distinct vertical division of the NP area, temperature inversions are most frequently responsible for effecting the local climate. During the days effected by anticyclonic weather, (case study July) temperature inversion was restricted in the MB-LIH and MB-DD stations‘ profiles almost every time. In terms of the time duration, it represents a medium long inversion. The longest inversion took place on July 27, 2006 between the MB – LIH stations. It persisted for 6 hours (6:30–12:30) and related to weather situation A. In respect of intensity, the inversions were classified as slight-medium strong. The highest temperature difference (10.3°C) was observed on July 19, 2006 at 8:00 a.m. between the MB – DD stations also for the situation A.

The report demonstrates enormous time and spatial air temperature regime variability on the topoclimate scale. The georelief morphography, its relative superelevation and the site aspect principally participate in influencing the temperature regime in the surface boundary layer in the NP. The mentioned factors contribute to the development of local climatic effects, mainly in the genesis of surface radiation inversions. The above presented results demonstrate the need for a detailed study of meteorological elements that participate in the formation of sustainable topoclimate.

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REVIEW

Marián HALÁS

TOUŠEK, V., KUNC, J., VYSTOUPIL, J. et al. (2008): *Ekonomická a sociální geografie*. Plzeň: Aleš Čeněk, 2008, 411 pp. ISBN 978-80-7380-114-4

At the end of August 2008, the first comprehensive publication came out in the Czech Republic, whose ambition is to provide complex and at the same time complete summary of economic and social geography and its partial disciplines. Experts from three universities (Masaryk University in Brno, Palacký University in Olomouc, and South-Bohemian University in České Budějovice) cooperated on the publication. Authors of all chapters have long been dealing with the problems of economic and social geography, both as university teachers and within their research projects. Also, all the authors are closely related to the geographical school in Brno.

The authors have managed to put together a relatively apt picture about the development, situation and main trends of the contemporary economic and social geography. The chapters are made up by individual partial disciplines of the economic and social geography – population and settlement geography, agricultural geography, manufacturing geography, transportation geography, and tourism geography. The original idea was that the structure of the chapters would be identical, which was definitely not an easy task. Although the chapters come as separate texts with their own lists of references, their structure and the given scheme have been largely kept.

As a whole, the chapters on partial disciplines of the economic and social geography can be assessed at a very high level. The development and the macroview of spatial differentiation within the global setting are dealt with very clearly. I can see certain discrepancies in the descriptions and applications of new research methods, which are indicators of new approaches, trends and information on individual disciplines.

The following chapters are of different character: the introductory part called "Development of Modern Geographical Thinking", and two closing chapters entitled "Global Environmental Problems" and "Regions and Regionalization". All three aptly complement the key part on partial disciplines and, in my opinion, are the most important contributions of the publication. Apart from providing basic information, they also take a closer look and explain the theoretical and methodological background both theoretically (geographical thinking, regions and regionalization), and at the same time with respect to its application and research (environmental issues, regions, regionalization).

The clear arrangement of the publication is also largely due to indices at the end of the book which enable easy orientation throughout the texts. What is also of outstanding quality is the graphical layout of the publication in all chapters, the overall design of the book and all small details. I particularly appreciate the quality, clear arrangement and informative value of all graphical supplements. In any case, all pictures – even the ones that were taken over from other resources – were modified and are presented in an excellent technical and graphical quality and at the same time in a unified style.

The publication on "Brno geographers" is due to its complexity unique on the Slovak and Czech market and fills up a considerable vacuum and demand for a detailed geographical (spatial) publication of such kind. The last such book dealing with the issues of economic and social geography was "Základy teórie a metodológie socioekonomickej geografie (The Basics of Theory and Methodology of Socio-Economic Geography)" by Ivanička, which was published more than twenty years ago. The geographical community desperately needed such a publication also for reasons of its presentation, popularization and publicity. It should therefore become an inseparable part of every (not only geographical) library.

INSTRUCTIONS FOR AUTHORS

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Fig. 1: Souther part of Bystřice River Valley from Posluchov (Photo M. Vysoudil 2006)

Fig. 11: Temperature inversion in the Moravský Beroun (Photo M. Vysoudil 2006)

Illustrations related to the paper by M. Vysoudil

Fig. 4: Complete clearings with individual trees near Starý Smokovec in August 2005 (Photo V. Falťan)

Fig. 5: Unprocessed wind calamity near Vyšné Hágy in August 2005 (Photo V. Falťan)

Illustrations related to the paper by V. Falťan and M. Bánovský