

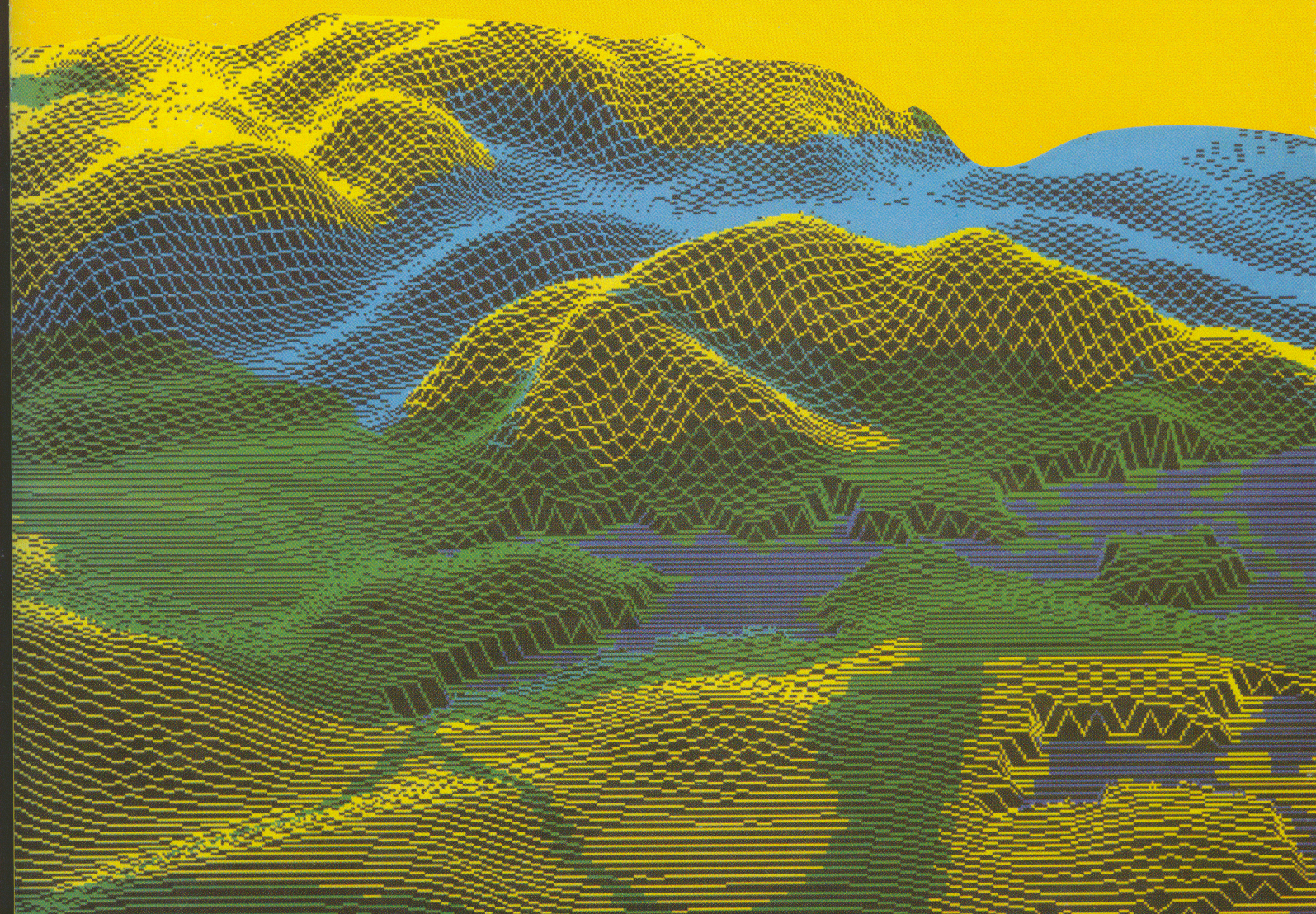
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MAILING ADDRESS

MGR, Institute of Geonics, ASCR
 P.O.Box 23, CZ-613 00 Brno,
 Czech Republic
 (fax) 42 5 578031
 (E-mail) ugn@isibrno.cz

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Territorial Aspects of Changes in Biodiversity in Military Training Fields

(A study made in the military training field Libavá with the use of satellite photography)

Jaromír KOLEJKA - Vítězslav NOVÁČEK - Jiří LAZEBNÍČEK

Abstract

Military training fields (MTF) are in the centre of attention during the last period. The study is the first approaching the more detailed analysis of the state of nature of the MTF Libavá on the basis of detailed knowledge of causes, ways and consequences of damage of the nature in the MTFs in the Czech Republic territory. The character of natural components of the environment in the MTFs is determined by the kind of a negative military activity, which is analysed with respect to environment devastation. Methods of the remote sensing have been utilised for detection of military changes of the nature. On the basis of false colour composites interpretation, an interpretation key was drafted and map data for MTF Libavá were plotted, recording the rate of military transformation of the environment and also the related phenomena of spontaneous regulation succession. The process of nature renewal is possible to be demonstrated on the MTF example after the removal of original forms of anthropogenic load, but also cases of enormous nature devastation. It is possible to observe vitality of natural forces and processes trying to restore the subtle balance in the landscape.

Shrnutí

Teritoriální aspekty změn biodiverzity ve vojenských výcvikových prostorech.

Vojenské výcvikové prostory (VVP) jsou středem pozornosti zejména v období několika posledních let. Předložený článek je pouze prvním přiblížením k mnohem podrobnější analýze stavu přírody ve VVP Libavá na základě podrobných znalostí procesů, způsobů a následků poškození přírody ve VVP na území České republiky. Charakter přírodních složek životního prostředí ve VVP je vymezen druhem negativního militárního působení, které je analyzováno se zřetelem na možnosti využití metod dálkového průzkumu Země pro detekci militárních změn v přírodě. Na základě interpretace nepravě barevné syntézy byl navržen interpetační klíč a byly vytvořeny kartografické podklady pro VVP Libavá s vyznačením stupně militární transformace životního prostředí s následným záznamem spontánní sukcese. Postupný průběh obnovy přírody můžeme pozorovat na příkladu VVP Libavá po skončení militárních forem antropogenního tlaku na přírodu, ale i v případech enormní devastace vojenského prostoru. Získané poznatky svědčí o značné vitalitě přírodních sil a naznačují možnosti uvedení přírody do původního stavu s cílem obnovení křehké rovnováhy v krajině.

Keywords : military activities, biodiversity changes, nature development

1. Introduction

Both the existing and former military training fields (MTF) attract attention of experts as well as that of non-technical public. Generally applied prohibition of entry for trespassers resulted in certain information chaos on one hand, and made impossible development of current social activities on the other, which often had an adverse effect on natural environment. It would not be possible to claim that from the naturalist point of view the areas were completely neglected. It is possible to say that, in principle, they were subjected to basic pedologic and forestry mapping, too. At the same time we can say that there was a whole range of other specialized research studies which were carried out in

these spaces such as basic geological and geobotanical surveys and the like. However, there was not enough time for thorough covering research, nor possibilities, sometimes not even understanding, and the studies once made gradually grew obsolete. A considerable deficit of works and results is being felt from the viewpoint of environmentally oriented study events.

At the beginning of the 90's, there were altogether 7 major military training fields in the territory of the Czech Republic, which served local garrisons of former Czechoslovak and Soviet armies, and other 34 dislocated MTFs or their parts. Their distribution was rather uneven in spite of the fact that they were practically surrounding all important urban agglomerations with

more than 100 000 inhabitants at a distance which was not too great (up to 50 km); see Figure 1.

As to covering variability of natural environment - natural landscape as that of a possible battle field, the MTFs are situated mainly in mountaneous terrain according to presumption of the then defense doctrine that military operations will happen in frontier mountains (Ivan at al., 1987). An important exception can be seen in MTF Mimoň, which is located in a moderate undulating terrain.

2. Nature of military injury to the biota within the MTF

Landscape sectors detached for training activities of armed forces in the past represent associations of landscape units differently sensitive to anthropogenic interference. Fundamental natural landscape elements are atmosphere, waters, lithosphere with land forms, soil and vegetation cover, possibly also radiation balance. Atmosphere (namely climatic conditions), lithosphere with land forms, and basic radiation balance are components which are more stable and more resistant to anthropogenic interference. Vegetation cover is particularly sensitive, waters and soils a bit less.

Losses on plant stands and relief, partially also on soils and exceptionally on waters (in the vicinity of the

source) were identified visually within the terrain survey. Other physical and chemical injuries to soils and waters require auxiliary laboratory examination and instruments. Terrain transformations and related changes in soil and biota can be evidenced in the case that there are anthropogenic, mainly military relief formations (Zapletal, 1969).

Extent and forms of damage to the vegetation cover are of a very diverse character. The majority of them represent mechanical disturbance of both the integrity of forest stands and that of individual trees, their groups, shrub and herb vegetation by military transport vehicles. The losses are contributed to by training activities of armed forces themselves as well as by non-organized activities. Similar disorders arise in connection with troops camping in the forest, when trees are felled to complete erection of camps in spite of felling being prohibited, exceptionally also as fuel. The open stands then often gradually succumb to drought, frost, wind and insects. In principle, these types of losses are currently reported also elsewhere, outside the MTFs, but in consequence of different impulses.

A typical form of mechanical damage to the stand is shooting with live ammunition. Although the shooting takes place mainly in reserved firing ranges, in the case of field shooting, forest stands become unintentional targets, too. Afflicted are usually the areas meant for these purposes, repeatedly, to save other stands if

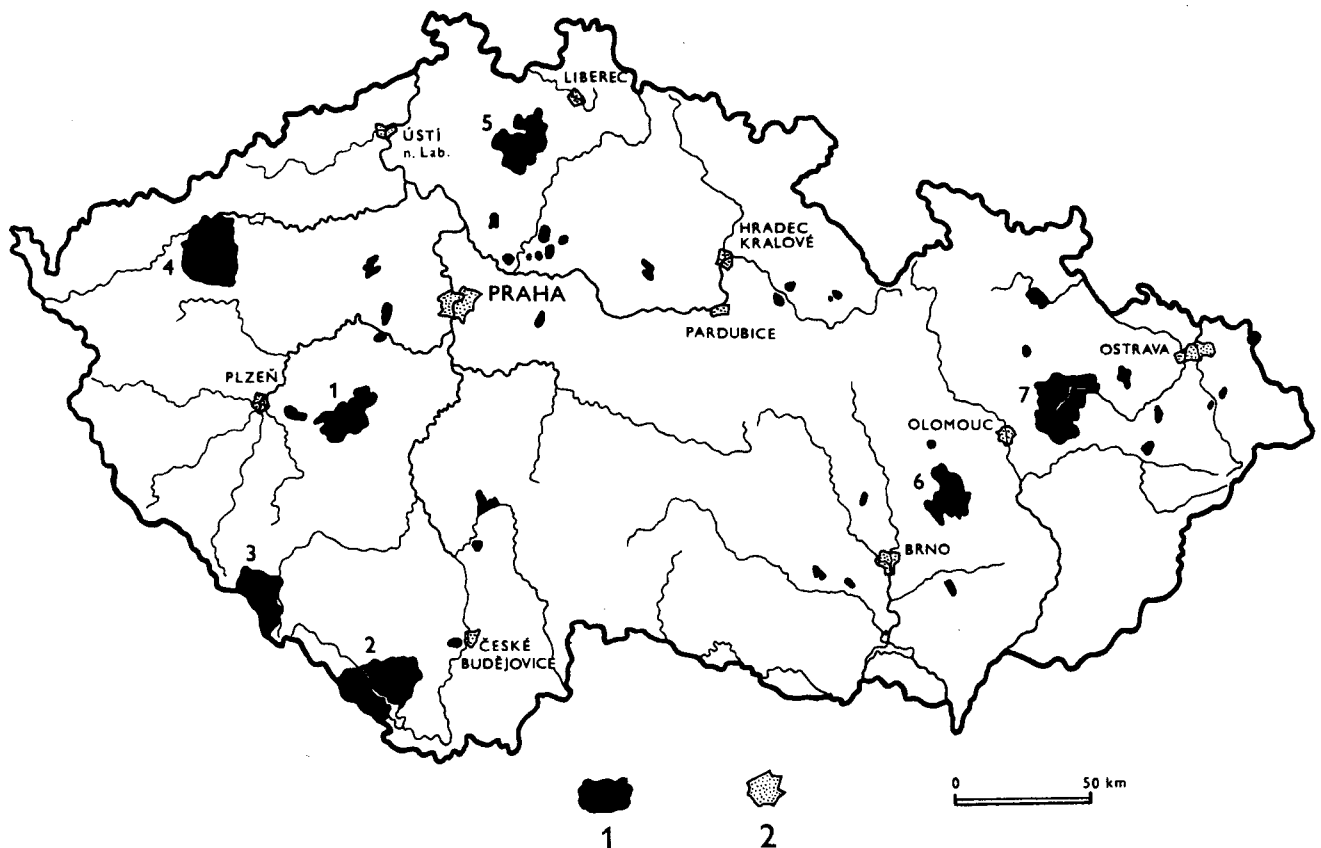


Fig. 1. The distribution military training fields in the territory of Czech Republic at the beginning of 90 s, which served local garrisons of the former Czechoslovak and Soviet armies. [1-military training fields, 2-urban agglomerations]

possible. Ammunition explosions result in various injuries to the trees and undergrowth. These activities of armed forces generally simulate extensive lightning effects. Further considerable economic (to lesser extent environmental) losses are caused by ammunition splinters. Metal fragments hit stems and tree crowns in the wide surroundings and these are practically excluded from normal commercial cutting since current machines and equipments cannot be used without the risk of their damage or injury to operator. Manual felling and processing of frequently very large volumes of timber are exceptional. Thus, the afflicted forest stands are left without any regeneration measures. In many respects they then represent an interesting object of natural historical science - often of considerable value - if they have been taken out from live shooting for longer period of time.

Driving and camping of troops as well as shooting with live ammunition have to do with fires. Inflammation often occurs at the contact of dry natural materials such as grass, moss, lichens, wood, etc. with parts of combustion engines, at burning slash or waste, fire setting, improper handling with flammables, ammunition explosions. Local importance have overgrown only the fires in MTF Ralsko which was originally utilized mainly by Soviet troops.

Intensive damage to the vegetation cover relates to concentration of driving tracks of both wheel and caterpillar military vehicles into relatively narrow corridors. This type of mechanical damage only exceptionally (MTFs Libavá and Mimoň) impacts extensive areas - as a rule only in localities of repeatedly held massive field trainings. These corridors of various sizes are practically without any vegetation cover. Soil cover here is practically non-functional due to extraordinarily compacted surface soil layers. Formation of impermeable crust at the very surface is often accompanied by formation of stone surface. Impermeability of the surface to water results in accumulated surface run-off. Severe linear erosion can be found at the places of repeated wheel run (so called "ruts") and disturbance by caterpillars (namely places where vehicles turn or change direction at moving on the slope).

Other mechanical damage to the vegetation cover is related to pioneer work of armed forces, which mostly consists in making trenches for vehicles, arms and corps, possibly firing ranges. Apart from some exceptions, these terrain formations are not removed properly after the drill ends and the relief is not put into its original condition again. Later, ever more new formations are being made, usually in intact areas. This is the way how biota, soil and relief are being changed in large areas.

Indirect anthropogenic damage to vegetation in the MTFs results from other disturbed natural elements of environment. Numerous are the cases of damage to soils and waters and consequent damage to biota by

crude oil products, this being of mainly local character, though. Larger extent (not intensity) can be seen in losses caused by air pollution in MTFs Dobrá Voda and Libavá.

Training of armed forces connects with a relatively rare phenomenon in cultural landscape. Vast areas utilized for training of corps - in spite of being interlaid with rutty corridors and transformed by engineering corps objects - gradually become overgrown with pioneer plants (herbs, shrubs and trees). These open landscape areas were originally used for farming (arable soil, orchards, pastures), but the original forms of use were mostly abandoned after establishment of MTFs. Centres of military conditioned nature succession in the former intensively exploited areas become both original natural and man-made (military, urban, agrarian. ...) objects. Dominant role is apparently being played by remaining riparian stands along untreated water streams. Continuous strips of shrubs and trees gradually come into existence along water courses, which interconnect separated forest sites by so called biocorridors-much desirable both as to their form and quality. This is the case of the so called "linear succession". Starting points for "point succession" are a.o. remnants of abandoned settlements since liquidation concerned mainly buildings and not trees should the demolition be made intentionally, at random or partially by weathering. Ornamental and utility tree vegetation (village greens, around sacral buildings, in front of houses and on private plots) has become a starting point for further spread of the woody species. Another important centre for tree species succession can be seen in articulated military terrain forms, namely if they include steep slopes or their bottoms are permanently or seasonally water-logged. Regarding the fact that tiny and articulated military forms of the relief such as trenches are abundant and widely distributed in the terrain, all-area succession is a typical form of succession in these places.

Therefore it can be claimed that military activities have controversial impacts on nature. In relatively well preserved original complexes (forests, meadows, water areas) they are accompanied by locally increased anthropogenic pressure, usually in the form of fitful attacks, though with longer-lasting consequences which are considered to be damage to natural environment. Detached localities currently disturbed by corps exhibit improving biodiversity thanks to prohibition to entry for public. After the originally intensively used landscape has been taken over by the army, the all-area anthropogenic pressure usually drops in spite of the fact that destructive impacts onto water, soil and vegetation may locally be increased and in some rare cases afflict even larger areas. However, it is usually not of permanent character with the exception of traffic corridors, firing ranges, etc. This relatively short-term but deep reformation of some nature components (mainly soil and terrain)

means their practical devaluation with the afflicted areas being left to their "natural" development for a certain period of time. They represent the area of practical experiment with spontaneous regeneration of the landscape, be it often with natural environment components otherwise intensively changed by man.

3. Methods of detection of biodiversity military changes in MTF Libavá by means of remote sensing

The MTF Libavá is situated westwards of the town Lipník nad Bečvou. It occupies frontier platforms of Oderské vrchy Mts., which are elevated 150-300 m above the neighbouring flat landscape of Hornomoravský úval (lowland) and Moravská brána (gate) into heights of over 600 m above sea level. They are built by layers of resistant Carbonic agglomerates and slates which bear only poor shallow cambiosol soils in the relatively cold and humid climate. The plateaux were deforested as early as in the Middle Ages and this should also be the date of origin to the typical elongated rural settlement in opened shallow upper sections of the valley. After 1937, when the military training field had been established here, population was gradually moved out and the villages turned to wilderness completely after the Second World War. The deforested plateaux were intensively used by drilled corps while the deep margin valleys mainly remained under forest cover. The MTF Libavá was directly used by the former Soviet Army for over twenty years.

Nature response to military activities can well be monitored by means of satellite and air photographs (Kuhn, Krull 1991; Marek, Furrer 1991). There are two satellite recordings that have been ensured for MTF Libavá, see false colour composites of the TM Landsat image of October 1988 [FCC : 2(B), 4(G) and 5(R) made at the scale of 1:500 000 on photographic paper] and original digital recording of August 1992. Starting point for comparison multitemporal study must be considered an available recording which can be provided with necessary supporting ground data at the least possible time delay, in the given case the image from 1992. According to the visualized image from 1992 there were altogether five main categories of damage/transformation to vegetation cover due to activities of armed forces defined for the purpose of mutual comparison in the given terrain, which are traceable in the both satellite photographs. They are as follows:

1. pronounced abiotic (bare) surfaces (rutted or compacted at the motion of military vehicles),
2. discontinuous herbaceous covers of damaged areas (disturbed by traffic and pioneer works),
3. herbaceous formations of mainly grasses, to lesser extent of ruderal vegetation species (in open terrains for infantry drills, training of tanks and artillery),

4. shrub stands (in areas with diverse engineering works in the terrain),
5. intravillan forests (in former settlements and their immediate surroundings).

Prior to processing, the image material was geometrically rectified into with the basic topographic map at the scale of 1:50 000. For this purpose it was necessary to carry out digitalization of false colour composite. With regard to completely different quality the images had to be evaluated by different procedures [1988 visual interpretation, 1992 normalised differentiated vegetation index (NDVI) and maximum likelihood classification (MLC) calculations], taking into account the above mentioned classification of areas, though. Differentiated were also urban areas, water areas, coniferous forests, mixed and broad-leaved forests, farming arable land and meadows. Material prepared in this way was subject to multitemporal analysis.

Detailed ground survey was repeatedly made on three key sites : "Jestřábí" (15 km²), "Nová Ves" (3,5 km²), and "Milovany" (18 km²) which were named by the formerly existing villages for convenience (Fig. 2). Interpretation of satellite data was made according to the ground data, results having been compared - at least partially - with the topographic map 1:50 000 of 1971. Any of the mentioned areas is representing possible type of landscape development in the course of intensive training of armed forces and after its end. Area development of the studied categories of military changes in vegetation was studied in each of the areas with a lot of statistic material available (Tab. 1).

4. Evaluating results of biodiversity dynamics according to changes of the vegetation cover

In the course of preparatory field research carried out in 1991-92 (Kolejka, Lazebníček, Nováček 1992) and during testing results of processed satellite photographs from 1993-94, numerous documents were accumulated which can to certain extent serve for deriving further developmental trends of landscape biodiversity in the studied MTF. It is necessary to point out in advance that to be able to define precise trends, we would have needed a much longer chronological sequence of information and similar material for comparison from many more tested sites than it was possible in our study. In spite of all this, the acquired data are relatively unique and allow to formulate certain general statements (Fig. 3 and 4).

A) The areas damaged by armed forces gradually regenerate in the following sequence: disconnected herbaceous covers - herb formations - shrubs - forest (of usually lower standard, originating from self-seeding forest tree species such as *Salix caprea*, *Salix aurita*, *Betula pendula*, *Populus tremula*). Site validation is

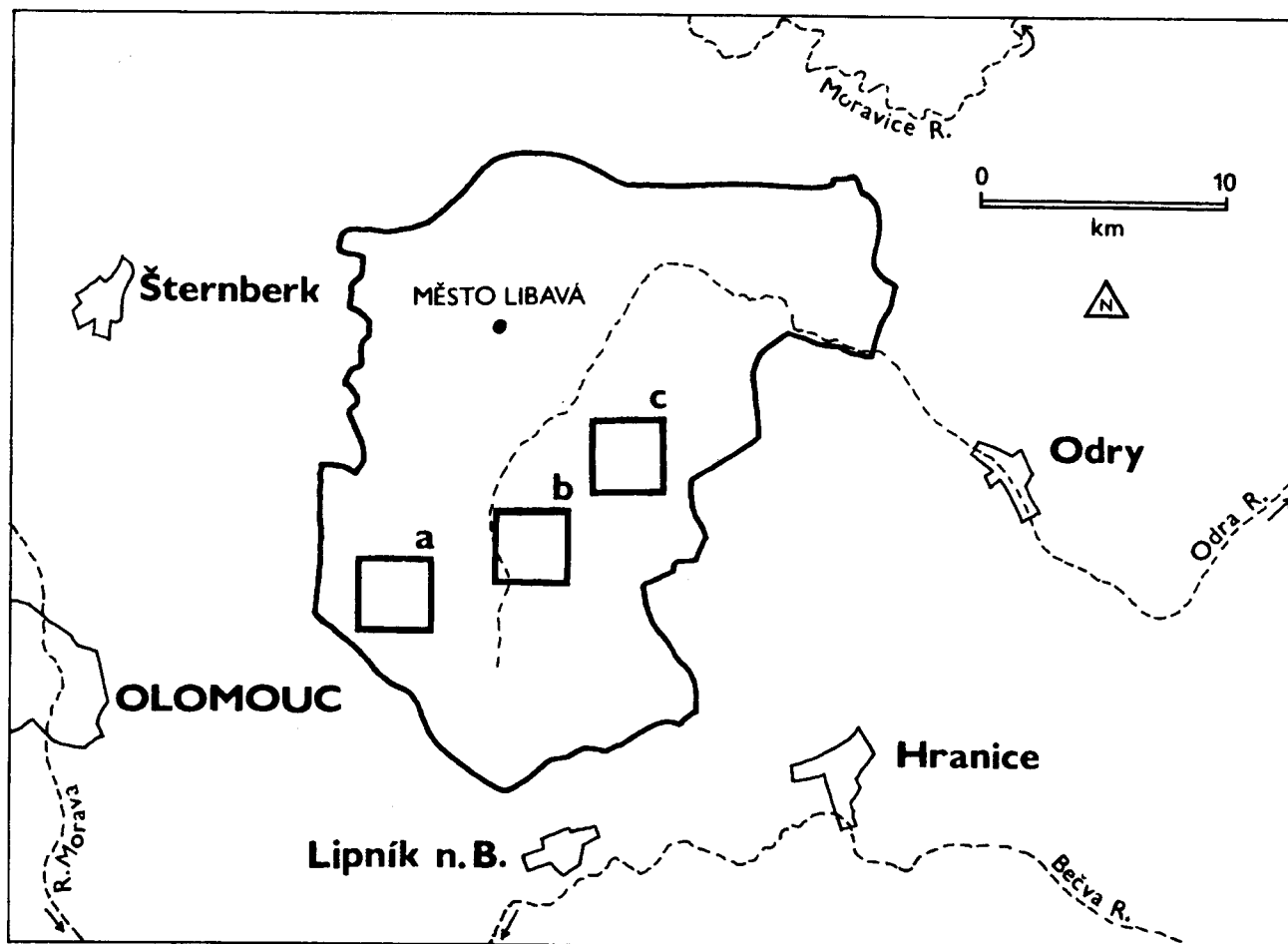


Fig. 2. The detailed ground survey in the MTF Libavá was repeatedly made on three key sites: a - "Jestřábí", b - "Milovany" and c - "Nová Ves" named after the formerly existing villages.

minimal in these cases since the plant cover hides artificial terrain roughness as well as injured or even water-logged soils. This process can be distinguished by rapid overgrowing with shrubs and bushes (short individuals of forest tree species) mainly to the detriment of herb formations. The overgrow usually comes out of humid localities (terrain depressions of all kinds and sizes) and is less applied in opened flat localities where grasses prevent growth of wood species (Fig. 5). The shrubs are a good indicator of anthropogenic relief transformation rate. According to experience gained through remote sensing interpretation, a period of five years should be sufficient to form a continuous shrub stand. For transition into the stage of "forest" we would probably need identical or a slightly longer period of time (older satellite photographs were not available for a site abandoned by corps).

B) Severely damaged sites (abiotic surface, compacted areas in traffic corridors) are incapable of spontaneous regeneration within realistic time and without man's support. Three years after the localities of this type were abandoned by Soviet troops, they have practically not changed at all. At lower damage (disconnected plant covers, partially also some ground

objects), overgrowing with mainly ruderal flora species is more pronounced and occurs in the form of disintegration of originally integrated areas into smaller complexes in the most favourable localities (more broken surface, humidity). The time needed for spontaneous regeneration can be only guessed due to deficient suitable material. Up to now, the two years of monitoring have not provided these data in relevant form (Fig. 6).

C) Regeneration of localities with occurrence of rare flora species (*Menyanthes trifoliata*, *Iris sibirica*, *Gladiolus imbricatus*, *Orchis majalis*, *Scorzonera humilis*, *Lilium bulbiferum*, etc.) is difficult due to intensive changes of original ecosystems and spontaneous rise of different new ecosystems (overgrowing of open and loose areas, alterations in moisture regime). The development leads to even sporadically preserved individuals losing their vitality. Artificial re-introduction is generally very involved and the choice of localities depend on assessment of the future fate of individual MTF sectors.

D) Corps activities are connected with intensive spread of invasion plant species such as *Lupinus polyphyllus*, *Calamagrostis epigeios*, *Melilotus albus*, *Tanacetum vulgare*, *Chamaerion angustolium*, *Cirsium*

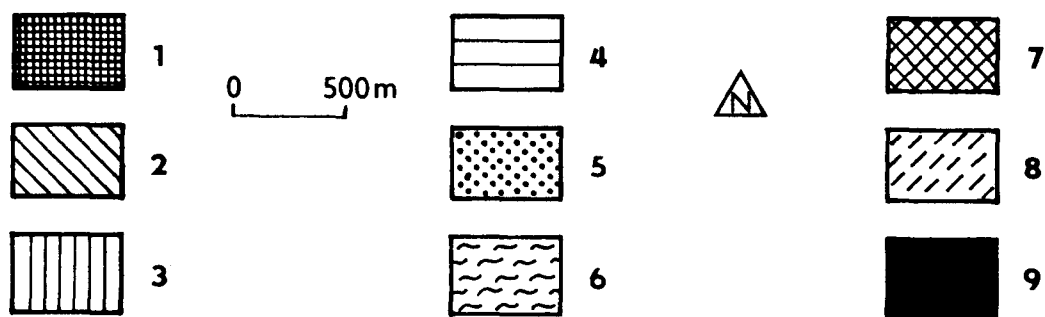
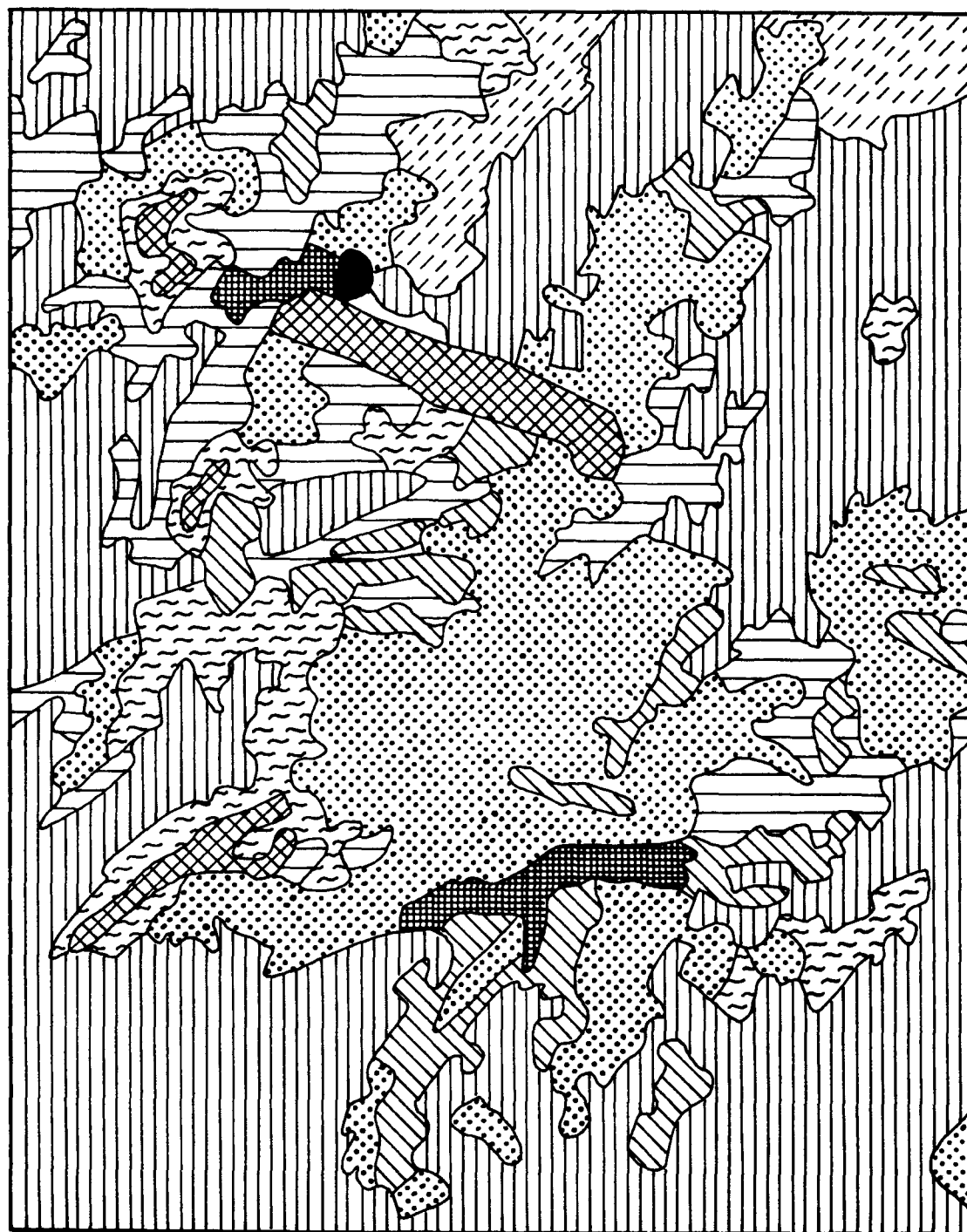


Fig. 3. Land cover of the military training field Libavá in 1988 (explanations see p. 39)

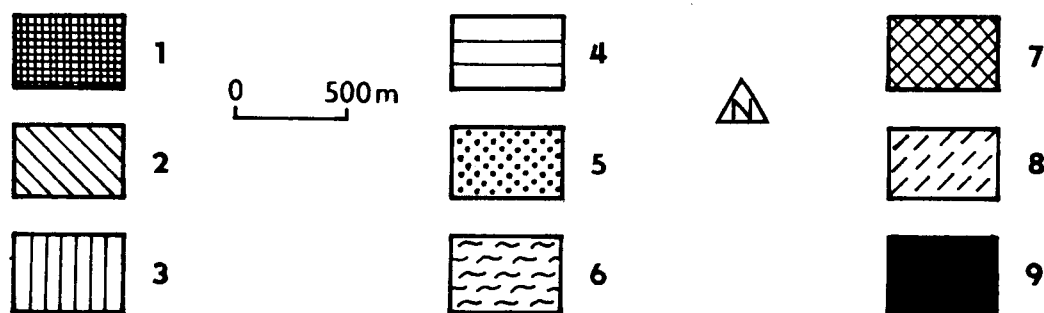
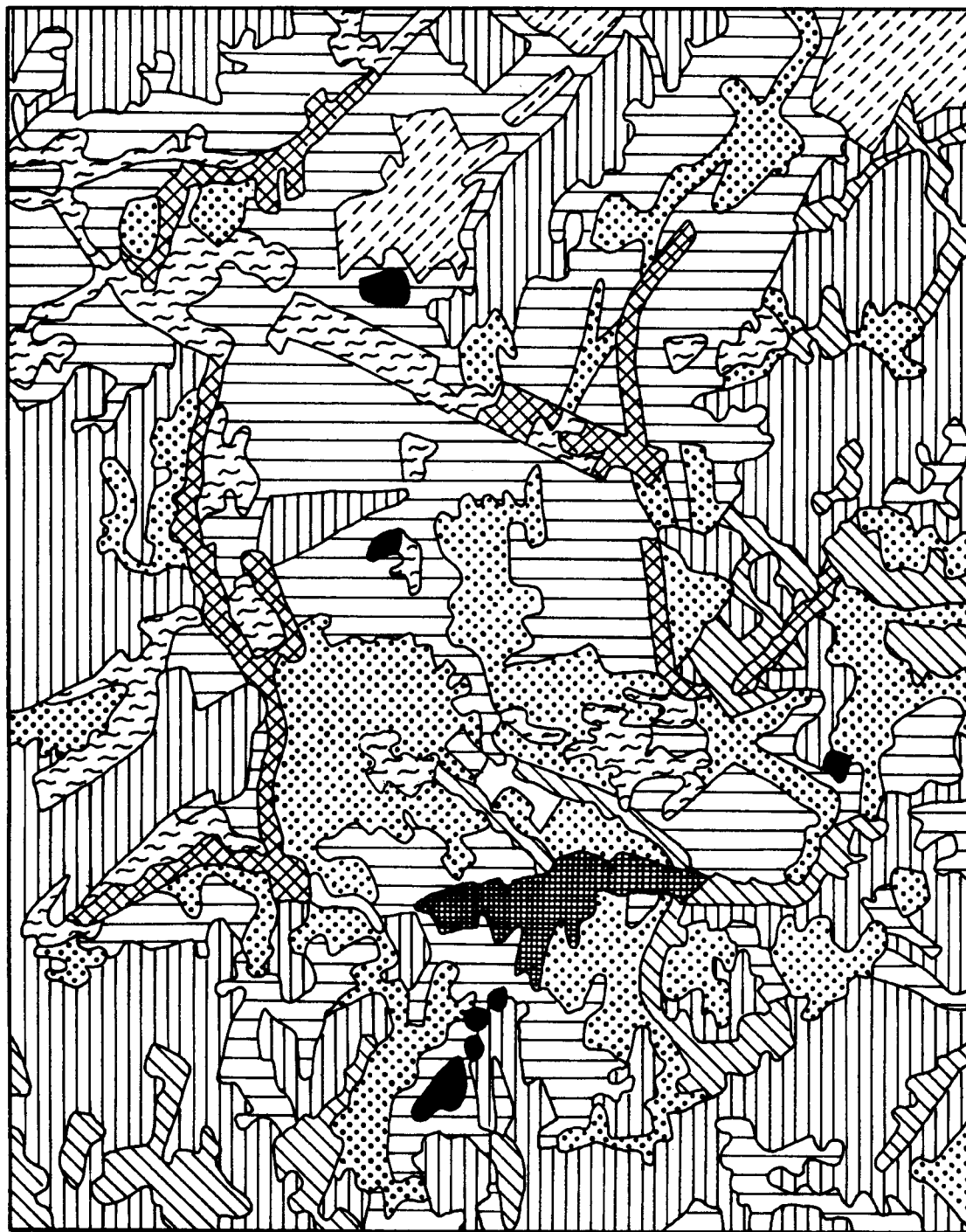


Fig. 4. Land cover of the military training field Libavá in 1992 (explanations see p. 39)



Fig. 5. Shrub stands in the open country cover artificial terrain roughness caused by pioneer work of armed forces, mean which the forest trees entered the originally grass areas.

Photo : J. Kolejka

arvense, *Echium vulgare*, *Geranium pratense*, *Agrostis alba*, *Petasites officinalis*, *Phalaris arundinacea*, *Scirpus sylvaticus*, *Filipendula ulmaria*, which force out, and at spontaneous development will be further driving out species of local flora. At weakened vitality of local species degradation of communities will most probably continue uncontrolled.

E) Land (terrain) shape development will be driven to gradual smoothing of military terrain roughness through the action of natural slope processes. This process will be contradicting to stabilization function of vegetation, and therefore the development will be growing weaker and longer proportionally to the biomass content per area unit of earth surface. Denuded land forms without any continuous vegetation cover are intensively decaying while the shrub stands conserve the formed terrain roughness to great extent, although they may be found in the stage of advanced destruction. Large ground objects such as tank and artillery firing ranges will most probably be preserved in the terrain. Complex development can be expected in compacted surfaces. Firm crust of up to 1 metre in thickness prevents more intensive weathering on one hand, on the

other hand it facilitates rapid run-off and water accumulation in active gullies. Crust weathering and overgrowing with vegetation will weaken intensity of erosion and gradual stabilization and overgrowing of gullies can be anticipated.

F) Major activity leading towards relatively fast recovery of the losses is agriculture. It participates to the decisive extent at recultivation of the most damaged areas. Water management (treatment of run-off) and forestry (plantation of cultural forest, unfortunately mostly the coniferous one, renovation of forest roads) will be applied to lesser extent. However, neither forestry nor agriculture contribute to improvement of biodiversity as they introduce only a narrow range of commercial species on large areas. Nevertheless, they increase economic value of the area.

G) To certain extent, the previous military activities led to increased retention capacity of the area as to amount of water retained in space not in reservoirs. On bare soils the run-off was locally accelerated. Differences in run-off among localities (areas of conversion military relief microforms and macroforms under shrub stands and in the forests except for bare soils) will

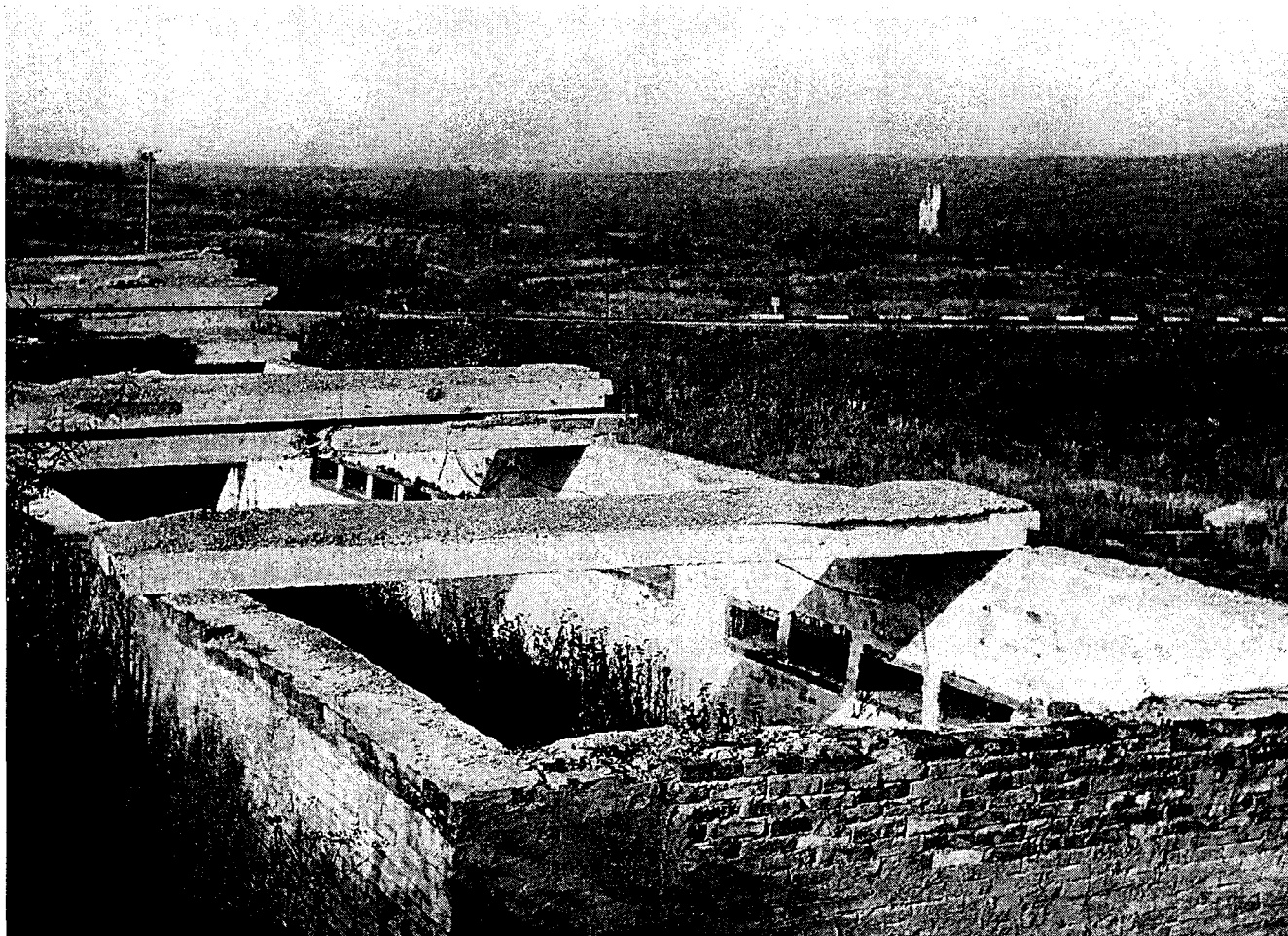


Fig. 6. Abandoned old settlement (former "Jestřábí" village church ruine in the background) and Soviet army buildings became cores of spontaneous reforestration.
Photo : J. Kolečka

gradually become less pronounced and it is to be expected that the resulting water capacity of the area will be higher than before opening the MTF in 1937. This development is connected with the increase in number of species and individuals of hydrophilous plant and animal species. Different is the situation in terms of water quality, particularly that of underground water which was not studied to greater details. At interpreting the satellite photographs, registered active dumps were classified as abiotic surfaces whilst hurriedly covered and planted dumps before dislocation of the Soviet army remind forest steppe formations. The both types of dumps should be given special attention in the future (Fig. 7).

5. Conclusion

The former MTFs represent areas which became a scene of unintentional experiments with nature. In them it is possible to demonstrate both the process of biodiversity recovery after original forms of anthropogenic pressure have been relieved or removed, and cases of enormous devastation of nature. A special case should be seen in spreading belligerent kinds of biota to the

detriment of autochthonous species and spread of introduced kinds of biota. In all these cases we can observe vitality of natural forces and processes attempting at a new equilibrium in the environment. Thanks to diversity of human impacts into nature as well as to their different age, natural components can be found in different stages of development or regeneration. It is not possible to say that the measure of vegetation cover transformation is a precise measure of conversion of the locality. In contrast, it often happens that the most afflicted localities become -after some time- oases of high biodiversity be it not only of natural species, and centres of nature development in environment affected by the man (in this sense there is a parallel of presently protected ancient castle hills - for protection of once treated areas).

ACKNOWLEDGMENT. This research was implemented as Grant No. 61401 which had been provided by Grant Agency, Academy of Sciences of the Czech Republic. Many works were made with direct assistance of colleagues from the Remote Sensing Laboratory of the Institute of Landscape Ecology, Academy of Sci-



Fig. 7. Hidden parts of the Soviet army waste dumps with short coniferous stands and grass look naturally (in the background) and can be detected in the field only in the neighbourhood of abandoned uncovered dumps.

Photo : J. Kolečka

ences of the Czech Republic in České Budějovice, GIS Unit at the Department of Geography, University of Salford, United Kingdom and Canadian Centre of Remote Sensing at the Ministry of Natural Resources,

Ottawa, Canada. Many enthusiastic workers of military forests and farms took part at collecting the supporting field data in all MTFs in the Czech Republic. Authors' recognition belongs to all of them.

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Table 1 : Territorial changes of the land use in the MTF Libavá between 1988 and 1992

cover type	percentage of the key site area					
	Nová Ves		Jestřábí		Milovany	
	1988	1992	1988	1992	1988	1992
intravillan forest	6.0	3.0	2.0	5.0	3.0	3.0
self-seeding forest	0.0	3.5	4.0	4.0	0.0	2.0
man-made forest	25.0	5.5	17.0	18.0	31.0	36.5
shrub stands	38.0	20.0	24.0	29.0	43.0	16.0
continuous herbaceous cover	17.5	35.0	17.0	11.0	9.0	30.0
discontinuous herbaceous cover	9.0	0.0	16.0	9.0	12.0	4.0
arable land	4.0	33.0	13.0	16.0	1.5	7.0
barren land	0.5	0.0	7.0	8.0	0.5	1.5

Explanations to the Fig. 3 and 4 :**A) FOREST STANDS**

- 1 - intravillan forest
2 - self-seeding forest
3 - other forest

B) TRAINING FIELDS

- 4 - shrub stands
5 - continuous herbaceous cover

- 6 - discontinuous herbaceous cover

- 7 - barren land

C) AGRICULTURAL AREAS

- 8 - arable land

D) WATERS

- 9 - fish ponds

Authors addresses

RNDr. Jaromír KOLEJKA, CSc.

Department of Environmental Chemistry and Ecotoxicology

Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

RNDr. Vítězslav NOVÁČEK, CSc.

Academy of Sciences of the Czech Republic

Institute of Geonics, Branch Brno

Drobného 28, P.O. Box 23, 613 00 Brno, Czech Republic

Ing. Jiří LAZEBNÍČEK

Institute for management of the military forests and farms

783 63 Velká Bystřice, Czech Republic

Reviewer

Doc. RNDr. Alois HYNEK, CSc.