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Conservation and management of forest patches and corridors in suburban landscapes

Janez Pirnat*

Department of Forestry and Renewable Forest Resources, Biotechnical Faculty, University of Ljubljana, Vecna pot 83, SLO-1000 Ljubljana, Slovenia

Abstract

Forest patches and corridors in the suburban landscape can be viewed as stepping stones between urban forests and forests in the adjacent forested landscape. The construction of a motorway around Ljubljana, Slovenia, has broken up, to a large extent, natural connectivity between urban vegetation and natural vegetation in the suburban landscape. A sample section of the planned Ljubljana–Maribor motorway traversing a case study area was used to show that the motorway will severely affect several tree corridors and break up forest patches in the suburban landscape north-east of Ljubljana. Existing forest patches and corridors enable migration between larger forest complexes to the west and east. The proposed section of motorway traversing the study area will break up most of these interconnections or at least aggravate the situation. Data on land uses and on the arrangement of forests, forest remains, corridors and tree belts in the study area were collected using satellite images. A model of a new connectivity was established using GIS. This study suggests that new corridors of trees be established along the motorway to connect the fragmented remains of the ecological infrastructure. Such a network of forest patches and corridors would represent a higher connectivity of natural vegetation and would constitute a necessary tool for the preservation of interconnections between urban and suburban forests in the suburban landscape. These areas of natural vegetation could also be one of the solutions to the conservation of biodiversity in the urban forests of Ljubljana.

Keywords: Suburban forest; Motorway disturbance; Ecological structure; Landscape ecology; Planning

1. Introduction

At the end of the 20th century it is evident that current human activity is making a marked impact on the future development of landscapes and regions worldwide. Thus, Forman and Collinge (1997) were justified in asserting: "The future is not just what lies ahead; it is something that we create." Many human activities cause changes in the cultural landscape deliberately, and some unintentionally. Urban landscapes are no doubt the most changed areas of Earth and urban forests can be regarded as the most natural part within urban landscapes.

Urban forests in Slovenia as defined in Slovenian part of report COST Action E12, Research and Development in Urban Forestry in Europe (Oven et al., 1999) represent forests, parks (i.e. woodland resources) in urban areas that are — due to their environmental and social, rather than production functions and benefits which they have for the citizens — regarded, proposed and in one period of time declared as a forests with special purpose. Urban forests are

* Tel.: +386-61-123-1161; fax: +386-61-271-169.
E-mail address: jpirnat@uni-lj.si (J. Pirnat).

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situated within a town area, they are part of city infrastructure and are daily accessible by means of public city transport, cycling and walking to at least a part of the habitants. A special management plan for these forests exist or shall be proposed in the near future. The production role of the urban forests, declared as the forests with special purpose, diminishes and their social and environmental roles increases.

On the other hand the suburban forests represent forest areas just outside cities on the suburban fringe. Their timber production is equally important to non-timber forest functions. In the present case study suburban forests are arranged in an agricultural landscape as forest patches and corridors that make an important connectivity network between urban forests within the city area and the traditionally production forest matrix which is surrounding the agricultural landscape. Beside having timber production, recreation and amenity value they act as stepping stones for several migratory species, meaning that they are important also for maintaining biodiversity in urban forests and suburban fringe. In this way urban forests may retain living connection with the natural environment.

After World War II, agriculture in developed countries rapidly became industrialised and modernised, and new technologies led to changes in the agricultural landscape. Areas of arable land were very often coalesced into larger complexes. As a result, some ecosystems (e.g. forests) and landscape elements (e.g. hedges, solitary trees, tree corridors) vanished or greatly diminished. All these landscape elements have represented characteristic features of a certain landscape. In addition to their aesthetic appeal, they also have a number of other functions (Pirnat, 1991).

The development of landscapes is characterised by changes in spatial arrangement and in the proportion of individual ecosystems (Fry and Sarlöw-Herlin, 1997). In the course of development, forests were cleared to make way for agricultural land use, along with settlement in all places with natural conditions (relief, soil, water) suitable for farming. Due to the changing land use, there are now fewer remnants of the former vegetation than in the past. Surviving remnants in the landscape are, however, often the most valuable. In most cases, their survival is due to special natural and social conditions. Among natural conditions are, for example, inferior soil conditions that are less suitable for farming, such as shallow or poorly drained soil. Among social factors are different examples of the division of agricultural land, and the role of the associated tree cover in representing the border between parcels of land (Pirnat, 1991).

In the agricultural landscape with prevailing agricultural land use on the one side and with forest patches, riparian and other types of tree corridors and individual remnants of forest trees on the other, flows of matter, energy and organisms within and between ecosystems can be evaluated (Forman, 1995). In such a landscape, forest fringes and remnants of trees and tree corridors represent a refuge for many plants and animals that would otherwise have been adversely affected by modern farming practices, such as large areas of uniform land use and high inputs of artificial fertilisers and chemicals (Collinge, 1996).

In addition to intensive agricultural production, the existence of the mentioned tree and forest infrastructure is also threatened by the expansion of cities and infrastructure development. In Slovenia, one of the more radical current land-use changes is the construction of a motorway network, which will be part of international European motorway corridors in a north–south and east–west direction.

The coexistence of natural ecosystems and human development in landscape is not always easy. Landscape ecology enables us to gain an integral insight into the development of landscapes, since it deals with their structure, functioning and changes occurring in them. Such an insight can therefore be regarded as a framework that can help identify key ecosystems for maintaining biodiversity in a landscape. Landscapes need to be studied most thoroughly in view of all the land use changes (Forman and Collinge, 1997). What matters is not only the existence of key ecosystems, but also their spatial arrangement. In a given landscape, we can thus speak of a landscape pattern which needs to be understood and taken into consideration if we wish to protect, in the course of land use changes, the most important parts of space vital for biodiversity and for the functioning of the landscape. According to Forman (1995), the following components are of key importance:

1. Strategic points.
2. The aggregate-with-outliers pattern.

3. The indispensable pattern of ecosystems which according to Forman (1995) accomplishes major ecological or human objectives, and no other practical mechanism is known to accomplish them.

According to Forman (1995), the following ecosystems or landscape elements are highly valuable in an agricultural landscape:

1. Large patches of natural vegetation, such as forest cover.
2. Main stream corridors with riparian vegetation.
3. Connectivity with corridors or with individual remnants, the so-called "stepping stones" between large patches.
4. Heterogeneous remnants of preserved ecosystems from a nearby forest matrix (e.g. remnants of forests, clusters of trees, solitary trees along paths, moraines and former meanders).

The basis of efficient planning lies in successfully combining all the four patterns.

2. Objectives of the study

The suburban landscape in question has for a long time been under human influence. The new motorway is the last item and will make an even greater impact on the structure of the cultural landscape. It will take up a certain area of the former land use, fragment and destroy habitats, and will break up the existing natural connectivity between urban and suburban forests north-east of Ljubljana. The motorway network therefore represents a severe hindrance for migration of a number of species, putting a great strain on the environment in the immediate vicinity. Conversely forest remnants and tree corridors will play a huge role in this new landscape, providing substitute habitats and migration corridors, absorbing noise and dust, and screening eyesores. A previous study (Pirnat, 1997) already pointed out a highly deleterious effect of the motorway around Ljubljana on natural connectivity between urban vegetation and natural vegetation in the suburban landscape.

The intent of the present study has been to investigate the importance of the so-called substitute habitats, that is, newly established patches and vegetation corridors, which should take over not just the role of lost forest areas but also establish a new framework of connectivity along the motorway. In this way a natural link between urban forests in the city and surrounding suburban forests will be retained. If we truly comprehend the importance of the functioning of natural ecosystems in a landscape as understood by landscape ecology, then urban forests cannot be treated separately from their wide background, since interconnections with natural background vegetation via stepping stones make preservation of their functioning possible.

3. Study area

According to the most recent regionalisation of Slovenia (Kladnik, 1996), the study area belongs to the macroregion of the Alpine world and the submacroregion Alpine plains, namely to the part Savska ravan Plain. The current study concerns the south-easternmost part of this plain, the regional unit Kamniškobistriška ravan Plain (Fig. 1).

The Kamniškobistriška ravan Plain was formed by subsiding. During the Pleistocene era it was filled in with deposits of alluvium. The plain is traversed by a number of watercourses which flow into one another or into the Sava River in its south-eastern part. Layers of gravel contain water, resulting in the whole area becoming rapidly saturated during rainfall. Soils are mainly rendzinas. In some places, eutric brown soils are also found (Perko and Orožen Adamič, 1998). Among agricultural land uses, meadows and fields prevail. Hills are covered with forests, which also occur as solitary patches in the plain on soils of inferior quality. Tree corridors and individual clusters of trees, found mainly along watercourses and often as solitary trees in the vicinity of villages, play an important role in the landscape.

The Kamniškobistriška ravan Plain was settled early in the course of history and has always represented an important cross-road. Due to the immediate vicinity of Ljubljana, the population of the area has increased in recent times, along with road transport. The construction of motorway network, part of which crosses the plain, represents the latest stress on the area.

Regionally, the plain is situated between the Škofja Loka Hills and the Polhov Gradec Hills on the west and the Posavje Hills on the east. The hills have a high

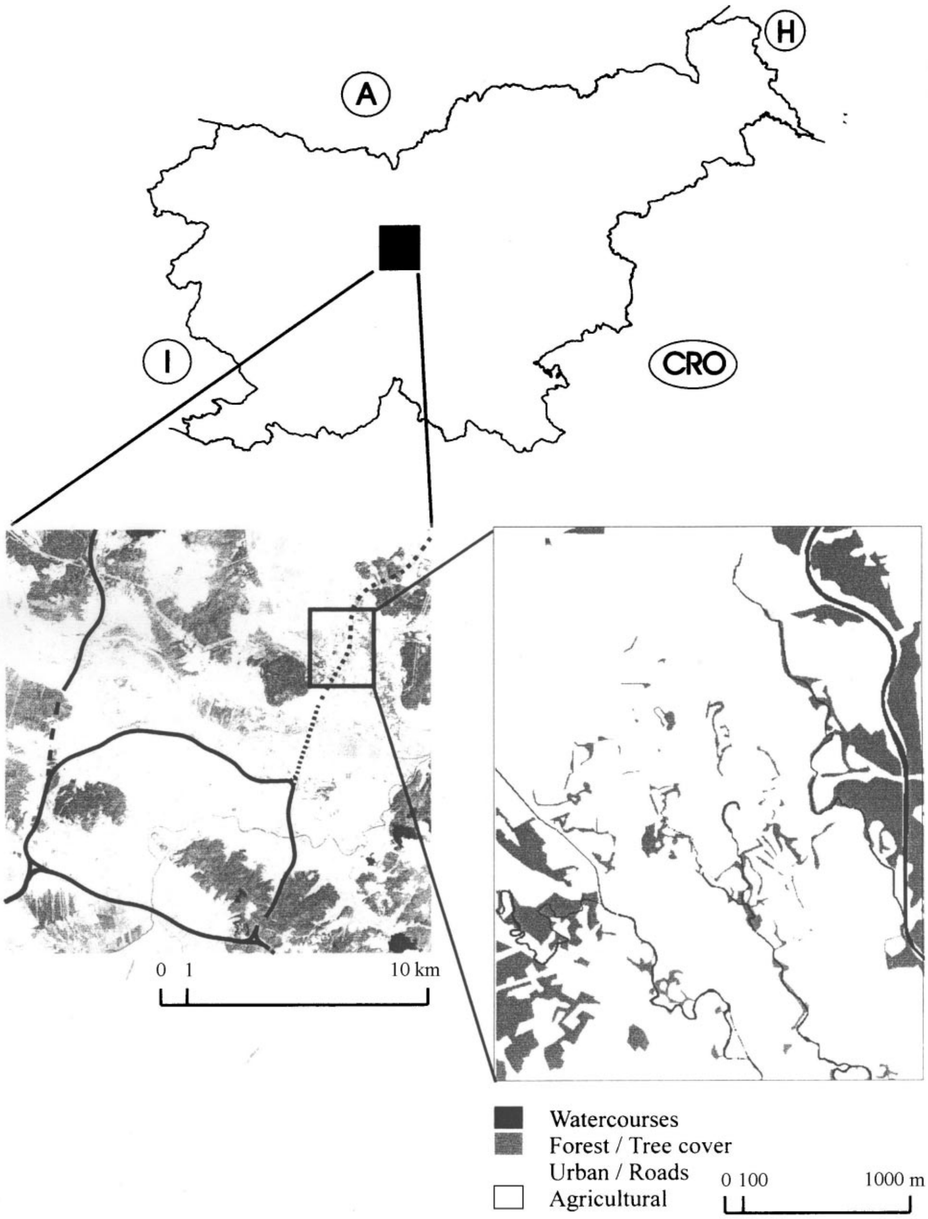

Fig. 1. An overview of Slovenia, illustrating the Kamniškobistriška ravan Plain with a satelite image of Ljubljana (bottom left) and the study area (bottom right).

proportion of forest cover (over 50%), while the Savska ravan Plain has a forest cover of approximately 37% (Perko and Orožen Adamič, 1998). These forest complexes ensure species diversity and genetic variety in the central, changed part of the agricultural land. From the viewpoint of landscape structure, the Kamniškobistriška ravan Plain can be divided into forest patches in the agricultural landscape, surrounded by a forest matrix on the fringes. Along the two main rivers in the area, the Pšata and the Kamniška Bistrica, tree corridors are running in a northwest–southeast and northeast–south direction, along with individual forest patches. These tree corridors and forest patches represent remnants of the most natural vegetation, forming a link between patches of urban tree corridors in the city of Ljubljana and the surrounding area north-east of Ljubljana (Fig. 1). These are remnants of the Robori–Carpinetum association with a preserved natural tree composition.

In hedges and forest patches, a number of animal species are to be found. Predatory species from the top of the food chain include weasel (*Mustela nivalis*), red fox (*Vulpes vulpes*), goshawk (*Accipiter gentilis*), sparrowhawk (*Accipiter nisus*), little owl (*Athene noctua*), and also rare bird species such as kingfisher (*Alcedo atthis*), dipper (*Cinclus cinclus*), and water rail (*Rallus aqauticus*).

Forests and their remnants are closest to the city of Ljubljana in a west-northwest–east-southeast direction. This is also the direction in which all the main forest areas in the city of Ljubljana are situated, i.e. the forests of Rožnik, the Castle Hill and Golovec (Pirnat, 1997). The forests and the remnants of urban forests in the city of Ljubljana are relatively well-connected with preserved forests situated in the west-northwest–east-southeast direction, but much less so in the southwest–northeast direction, where corridors of riparian trees and individual forest patches are often the only link with the natural landscape. These patches and corridors act on the landscape level as stepping stones for the migration of species in the northwest–southeast and northeast–south direction. They are therefore considered an important forest structure element in the suburban agricultural landscape, and are a potential source of genetic variety and species diversity in connection with urban vegetation.

The motorway Ljubljana–Maribor will break up this connectivity, particularly in the agricultural landscape along the rivers Pšata and Kamniška Bistrica (Fig. 2). There will therefore be an increase in the significance of interconnections between corridors of natural vegetation running parallel to the location line of the motorway, which could to a certain extent mitigate its adverse effect. When new areas of forest patches and tree corridors are planned, they should be based, as much as possible, on the existing important

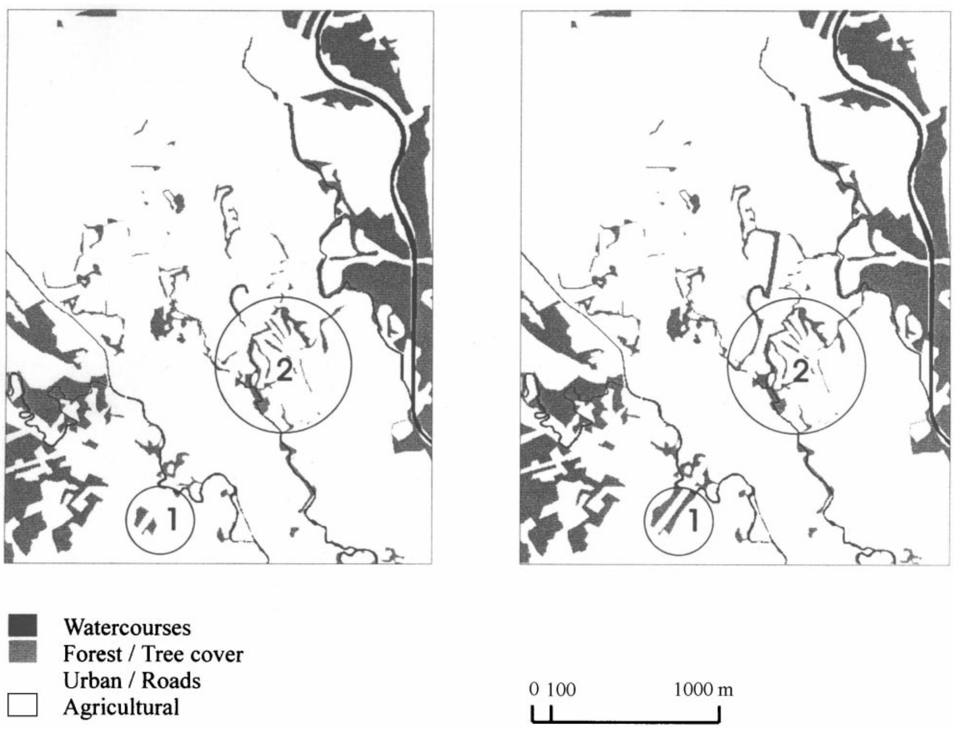

Fig. 2. Study area with the location of the motorway (left), and with a proposal for new forest connectivity (right).

elements of ecological infrastructure which should therefore work out as a backbone of this spatial solution according to Forman (1995).

4. Methods

Data on land uses and the arrangement of forests, forest remnants, corridors and tree belts were collected using satellite imagery. For the purpose of this study the satellite IRS-1C with the sensor PAN (a line screen camera) with a 5.8 m resolution was employed. From satellite images taken on July 16, 1997, a quadrant of $23 \times 23\,km^2$ in size covering Ljubljana and its environs was selected. Within it, a section of 690 ha running along the location line of the motorway was studied in detail.

The selected satellite imagery was transformed into the Gauss–Krueger co-ordinate system using 27 ground control points. The root mean square (RMS) error of recorded locations from their true locations was minimum with this number of control points employed. For a polynomial transformation of the second order, the Desktop Mapping System Version 4.0 (DMS) programme, developed by R-WEL, Inc., 1995 was used. Co-ordinates of the ground control points were derived from basic topographic maps at 1:5000. The cross-roads and edges of buildings turned out to be most suitable control points. The DMS programme was also used for the on-screen digitising of land uses to determine individual forest patches, tree corridors, and groups of solitary trees in the satellite images. The data collected in this way were transferred onto the PC environment of the geographic information system programme package IDRISI 2.0, developed in The Clark University, 1997, for spatial evaluation (determination of areas of individual land uses and forest structure elements and their proportions, determination of distances between them). On the basis of spatial distribution of forest structure elements, it was possible to propose new connectivity in the form of corridors and patches.

5. Results and discussion

Due to the high resolution of the satellite sensor and the clear layout of the low-lying area of the agricultural landscape, it was possible to differentiate between all forms of preserved natural tree vegetation. In the sample area, remnants of preserved natural vegetation were found in the form of smaller forest patches, tree corridors in the agricultural landscape, riparian tree corridors, groups of trees and shrubs, and individual solitary trees in the agricultural landscape. These are referred to as forest structure elements (Toth, 1988). The high resolution also enabled the clear differentiation of the smallest clusters of solitary trees with equal validity. In the agricultural landscape these are often an important refuge for migratory animal species, particularly in the absence of other forest structure elements (Pirnat, 1991). Forests structure elements ranged in area between 0.0025 and 12.95 ha. The elements grouped according to their area are presented in Table 1.

In dense patches, the minimal distance of inner space, i.e. half of the length of the shortest axis of the patch, is an important factor. In this case, however, such information is insignificant, as tree corridors with a minimal width and without inner space are prevalent. In addition to area, their arrangement or the distance between them is of importance. According to Wildermuth (1980), elements of natural vegetation should not be spaced more than 300 m apart to allow migration of many faunal species between them. Roughly the same distance seems to be important for plant dispersal capability (Huntley and Birks, 1983; Johnson, 1988). Table 2 shows the area of forest structure elements, their proportion, and the distance between them.

As evident from Table 2, the distance of over 300 m between hedges and patches of natural vegetation is found only on a mere 6% of the surface of the sample area. The motorway will constitute an interference, not only because of area loss, but also due to changes

Table 1
The number of forest structure elements according to area classes

Area (ha)	Number of forest structure elements
<0.05	43
0.05–0.49	49
0.50–0.99	14
1.00–4.99	12
5.00–9.99	5
10.00–15.00	3
Total	126

Table 2
The area and its proportions according to different distance between forest structure elements

Distance (m)	Area (ha)	%
0–50	338.47	49
50–100	128.47	19
100–150	78.51	11
150–200	51.92	7
200–250	32.46	5
250–300	20.25	3
Over 300	39.92	6
Total	690.00	100

in migration corridors. Though it will run mainly across agricultural land, the motorway will also break up some strategic points of preserved natural vegetation in the agricultural landscape. Table 3 shows proportions of land uses in the sample area before and after the proposed motorway development. The location of the motorway and proposed forest connectivity is seen in Fig. 2.

Due to motorway construction, 1.55 ha of forest will be removed from the sample area. It will partly break up forest patches but will mainly affect corridors of riparian vegetation. Apart from areas over which motorway bridges will be built, there will be no loss in area under water. The minimal loss in the column ‘‘Urban and roads’’ refers to the area of local roads and field paths, which will either be connected via underpasses and overpasses or abandoned. The largest removal of land area within a specific land use (10.5 ha) will involve agricultural land.

In terms of quality, what is more important than the loss of the natural ecosystem (i.e. the forest) is the loss of this area in the landscape and interrupted migration corridors. The new connectivity will have to be established around strategic patches and corridors of natural vegetation. The two key strategic elements are, in this case, the biggest forest patch in the middle of the study area (No. 1 in Fig. 2) that will be cut into two small fragments by the motorway and the intertwined network of tree corridors and riparian corridors around water spring (No. 2 in Fig. 2) broken up by the motorway. On account of their central location, these are the areas around which substitute areas of trees and corridors must be planned in the future. In this way, the two points would be connected with one another and/or with the surrounding area in order to preserve the connectivity in the form of the so-called ‘‘stepping stones’’ between urban forests and natural forests in the suburban landscape north-east of Ljubljana.

As a result, a theoretical model of the proposed new connectivity was established, based on a visual assessment of the distribution of forest structure elements around strategic areas (Nos. 1 and 2 in Fig. 2, right). According to this model, the establishment of as few as 4 ha of additional forest corridors in the landscape will prove significant in connecting the central part of forest structure elements with natural forests in the background and with one another (Fig. 2). These new corridors would thus act as inter-source linkages (Yu, 1996) and constitute the backbone of a network of natural features in the changed agricultural landscape, which could be referred to as the territorial system of ecological stability (Kubeš, 1996), especially if connected with wildlife underpasses under bridges. This backbone of natural features should remain, as a rule, as finite as the location of water

Table 3
The area of land use before and after the construction of the motorway, both with and without a proposal for planting tree corridors

Land use	Area of land use (ha)		
	Before construction of motorway	After construction of motorway	With new tree corridors
Forests/trees	112.05	110.50	110.50
New forest	–	–	3.98
Watercourses	13.39	13.26	13.26
Urban/roads	60.65	60.57	60.57
Agricultural	503.91	493.41	489.43
Motorway	–	12.26	12.26
Total	690.00	690.00	690.00

courses. All possible changes and interventions should be planned in such a way that it would ensure the undisturbed functioning of new linkages and substitute habitats. This connectivity between the urban and suburban landscape is of particular importance in ensuring biodiversity at all the three levels according to the Convention on Biological Diversity (1992): genetic variety, diversity of species and ecosystems in urban forests as well. Without adequate connectivity with suburban forests, urban forests are but an isolated patch which could increasingly resemble a park rather than a natural ecosystem with a characteristic structure and function.

6. Conclusions

Urban forests will remain as forest ecosystems if we manage to preserve their natural structure and functioning. Therefore it will always be of importance if we attempt to preserve natural connectivity between urban and suburban areas of preserved forests. Urban and suburban forests will therefore constitute an integrated whole, especially in terms of ensuring biodiversity at all the three levels. Forest patches and tree corridors, and various minority ecosystems such as marshes, puddles, hillside springs and the like, are thus of crucial importance for ensuring biodiversity in both suburban and urban forests. The construction of a motorway will lead to fragmentation of small but important remnants of forests. To ensure the functioning of a forest, it is therefore vital to establish substitute habitats, especially in critical areas. A prime requirement for the management of a cultural landscape is that the natural state of the environment is maintained as much as possible or that a damaged biotope is restored. The requirement for restoring a damaged biotope is based on nature conservation principles of entitlement to compensation for induced damage. When the natural state is re-established, we follow, as a rule, the patterns of the existing arrangement of landscape elements in the landscape (e.g. individual trees and shrubs, forest patches, corridors and riparian groves). But to ensure and maintain biodiversity, it is vital to preserve a solid landscape framework, a network of inter-source linkages between the source of a strategic point and connecting elements (Yu, 1996). This rule should be taken into account when substitute biotopes are being established. In this particular case, only 4 ha of newly established forest patches and tree corridors would make a higher connectivity between forest fragments possible. Since owners of a property are not as a rule interested in such interventions and in forestation, we suggest that in such cases the investor of the motorway should purchase an adequately wide belt of land in critical areas, in which substitute habitats could be established.

Up-to-date satellite images with a high resolution (below 10 m) turned out to be an excellent tool for identification of sources of existing natural habitats, strategic points, existing biotopes and the so-called empty space, where elements of natural vegetation are absent or inadequately distributed. Therefore, such satellite images are an important instrument for the design of spatial solutions and for carefully planned management of tree corridors and forests in the suburban and urban landscape.

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