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ARTIFICIAL ENERGY INPUTS INTO SPRUCE LOWLAND FORESTS IN SUBURBAN LANDSCAPES IN SLOVENIA

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Abstract

Slovene forestry is concerned with nature conservation, but in the past, the species variety of forests has often been changed and, similarly as elsewhere in Europe, the share of forest with artificial dominance of Norway spruce increased. Based on the spatial model of landscape structure, we estimated the arrangement in conservation of suburban forests in eight Slovene macro regions. In the area of town Kočevje, we assessed artificial energy inputs in the forests lying within one kilometre large area used by inhabitants for daily recreation. In this area, 65 % of forests were categorized as forests with artificial dominance of Norway spruce.

Key words: Landscape structure, landscape changes, energy inputs, Norway spruce (*Picea abies* L.), Slovenia

UMETNI ENERGIJSKI VNOSI IN OHRANJENOST PRIMESTNIH GOZDOV NA SLOVENSKEM

Izvleček

Slovensko gozdarstvo je naravovarstveno usmerjeno, toda v preteklosti je bila vrstna sestava gozdov pogosto spremenjena in podobno kot drugje v Evropi se je povečal delež zasmrečenih gozdov. Na podlagi prostorskega modela krajinskea zgradbe smo ocenili razporeditev in ohranjenost primestnih gozdov v osmih slovenskih makroregijah. Na območju mesta Kočevje smo ocenili umetne energijske vnose v gozdovih, ki ležijo znotraj kilometrskega pasu mesta, na območju dnevne rekreacije prebivalcev. V tem pasu je kar 65 % gozdov sodilo v kategorijo zasmrečenih gozdov.

Ključne besede: Krajinska zgradba, spremembe krajine, energijski vnosi, smreka (Picea abies L.*), Slovenija*

INTRODUCTION
UVOD

In the 20th century, Europe focused a wide range of threats to the »traditional cultural landscapes«. They can be characterised by two different processes, land intensification and land marginalisation. Both have been addressed by several authors recently (ANTROP 1997; JONGMAN 2001; VAN EETVELDE / ANTROP 2004; NIKODEMUS *et al*. 2005). Yet few authors have focused more deeply into the role of forest and forested landscapes in these processes. However, it is the forests and forested landscapes that make a matrix of many European countries, facing increase in forest area (ZANCHI *et al*. 2007) but not necessarily improvement of its structure and landscape functionality (LARSEN 2005; SCHLAEPFER 2005).

It was estimated that the increase in the area of coniferous forests and the increase of the total amount of coniferous growing stock are the two most probable reasons for the increase in the storm damage (SCHELHAAS *et al*. 2003). Over the 1950-2000 period, an annual average of 35 million m^3 of wood was damaged in Europe by disturbances: storms were responsible for 53% of the total damage, fire for 16%, snow for 3%, and other abiotic causes for 5%. Biotic factors caused 16% of the damage, and half of this was caused by bark beetles. In most European countries, pure Norway spruce stands are considered highly unstable with regard to the mentioned disturbances (LARSEN 1995; LUEPKE *et al.* 2004). Teuffel *et al*. (2004) have estimated that there are 6-7 million ha of forests with artificial dominance of Norway spruce (*Picea abies* (L.) Karsten) in Europe, with 4-5 million on sites originally covered by broadleaved species. The widespread reliance on conifer monocultures has come into question and more stable site-adapted mixtures of species are under consideration or already employed (HANSEN / SPIECKER 2005; STANTURF 2005). The conversion of some Norway spruce forests to near-natural and often mixed forest is required, particularly for public forests. Moreover, the people's perceptions of forest have changed. It was assessed in Germany that the popularity of mixed forests remains on a steady level, whereas conifer forests have decre-

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ased in popularity at the benefit of deciduous forests (SCHRAML / VOLZ 2004). Planting broad leaved trees should decrease the risk of stand damage, but it was shown that the profitability of the latter does not reach the level of conifers (DIETER 2001; KENK / GUEHNE 2001), the transformation into beech stands leads to a permanent reduction of profitability (JACOBSEN *et al*. 2004; MOEHRING / RUEPING 2008).

Despite lower profitability of wood production, natural spaces and natural elements such as forests and trees have been seen as providing opportunities to ameliorate the trends of an increasingly sedentary population, increasing levels of mental stress related to urban living and contemporary work practices, and hazardous environments, e.g. air pollution (COST E39, 2007). The Slovenian Ministry of Health is aware of these trends and has therefore defined several priorities for the National Health Care Programme. The objectives of the plan are, among others: to tackle health inequalities; to modify lifestyle harmful to health, and to improve the quality of physical environment (PAULEIT *et al.* 2005).

Due to these facts, the importance of healthy environment – most common in a form of urban forest matrix – is strongly increasing in Slovenia as well.

As a newcomer to the EU, Slovenia is faced with several challenges, especially in the area of land use, multi-functionality and nature conservation. The total Slovene area comprises 20,273 km^2, and with its 2 million inhabitants, the country is rather small in the European context. However, Slovenia is known for its great relief diversity, distinct cultural landscape, architecture and settlement heritage, as well as rich traditional multifunctional ecosystems. The main characteristics of the population pattern are densely populated basins and valleys, which contain almost 60 percent of the population living in less than 20 percent of the country.

In contrast, less favoured areas (mountains, steep slopes and summits) cover 85% of the whole country, with restrictions to agricultural production (MKGP 2007).

As there are major geomorphologic zones in Slovenia, it was necessary to integrate the landscape assessment of Slove-

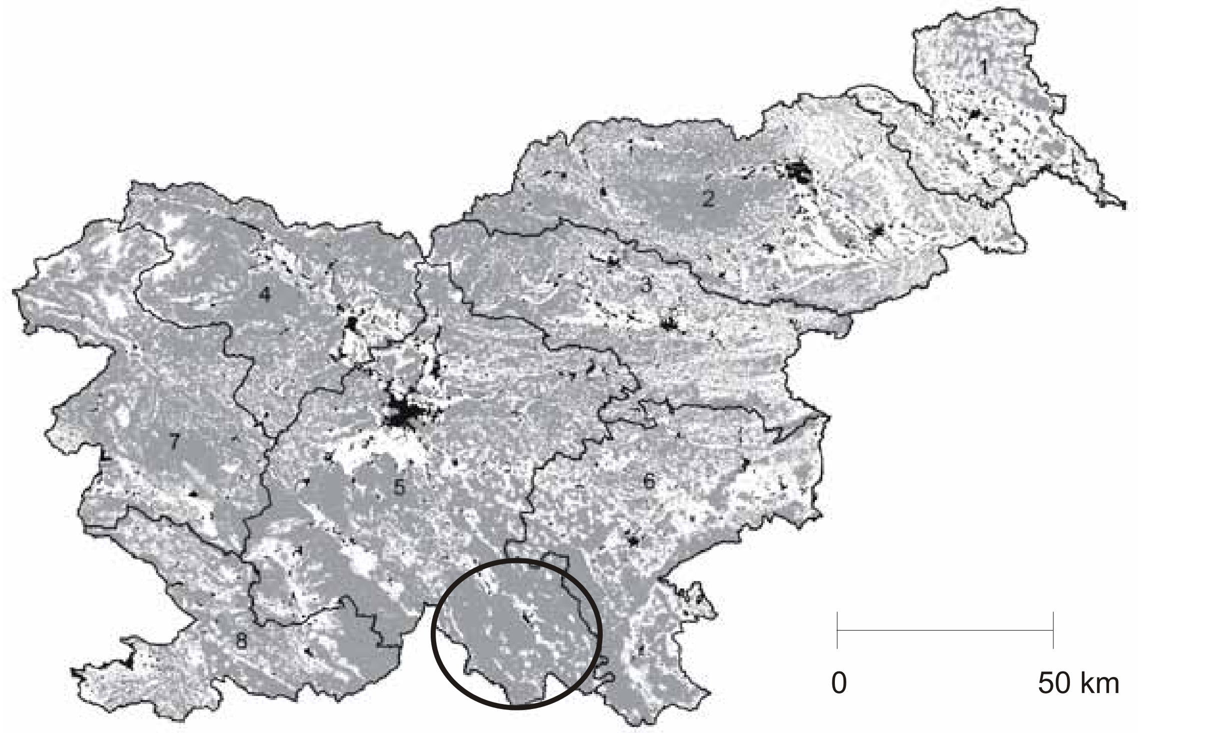

Fig. 1: Slovenian macro-regions, defined according to geographical and landscape- ecological characteristics (PLUT 1999). Grey colour represents forests, black are settlements. The study area is indicated by an arrow.

Slika 1: Slovenske makro regije, opredeljene po geografskih in krajinskoekoloških značilnostih (PLUT 1999). Gozdovi so označeni s sivo, naselja s črno barvo. Območje raziskave je prikazano s puščico.

Macroregions / *Makroregije*

1 *Pomurje* – the Mura River macro-region

2 *Podravje* – the Drava River macro-region

3 *Savinjska* – the Savinja River macro-region

4 *Gorenjska* - Gorenjska macro-region

5 *Osrednja Slovenija* - Central Slovenia

6 *Jugovzhodna Slovenija* - South-east Slovenia

7 *Severna Primorska* - Northern Littoral

8 *Južna Primorska* - Southern Littoral

nia into the spatial planning process. Landscape structure has therefore been assessed at the national and regional levels, based on sustainable regionalization of Slovenia. According to Plut (1999), the country is divided into eight macro-regions and 25 meso-regions (Fig. 1). Slovenian meso-regions were thus demarcated primarily according to the river basins that connect the landscape ecology webs within the areas of influence of regional centres (PLUT 1999). According to the final data of the 2002 Census (SORS 2002), approximately 51% of the population lives in urban settlements and 49 % in rural areas. According to the census data, Slovenia has almost 6,000 settlements. Ljubljana and Maribor are two largest cities with more than 100,000 residents, followed by Celje and Kranj with more than 30,000 inhabitants.

Slovenia is mainly covered by forest (59.8% of the country), agricultural land covers 32% and other land uses 8.2% (MKGP 2007). Forestry determines the structure and appearance of Slovenian landscapes and has a major role in nature protection. Furthermore, timber production has increased over the last fifty years, yet in the last five years the percentage of sanitary felling has risen from 21% in 2002 to 33% of the total cut in 2006, with the peak of 37% in 2005 (SLOVENIAN FOREST SERVICE 2007). The most common damage was caused by insects (especially bark beetles) with 64% of all damage caused in 2006. In the last ten years, the extent of sanitary felling of trees attacked by insects has risen from 81,000 m^3 in 1997 to 700,000 m^3 in 2006. The species most affected was Norway spruce, especially in the lowlands and where it was dominant (SLOVENIAN FOREST SERVICE 2007). Sites at lower and medium high altitudes are particularly vulnerable where the forest structure has been modified by man in previous centuries owing to the introduction of spruce. Such forests are likely to be a major problem in Slovenian forestry in the near future.

The future forest management policy in Slovenia should be aimed at sustainable resource use. The support role of Slovenian forests for nature protection (71% of NATURA 2000 sites are under forests) and other ecosystem services (well being, carbon sequestration) is widely recognized as being of key importance.

Sustainable forest management, which is already one of the standard practices in Slovenia, is a sound basis for the adjustment of forests to climate change. The key issue of the adaptation is the change of the forest stand structure. The basic guideline is an increased share of thermophilous species. The majority of Slovenian forestry experts favour a higher proportion of deciduous trees, particularly beech (BONČINA 2008).

To guide the forest stand structure, the monitoring of the status must be intensified as well as an assessment of the vulnerability of the most endangered lowland and sub-montane forests with a disproportionately high share of spruce. The idea we have tried to follow in our research was to establish a link between the amount and proportions of different forestry activities (production –silviculture –protection measured in terms of artificial energy input into different forest management classes) and their stability, following a logic that more energy inputs are required for the maintenance of vulnerable forests stands. Due to all these facts, it is necessary to study the amount of artificial energy inputs needed for the functioning of different types of managed forests, especially those with a high proportion of introduced spruce.

Based on the data of forestry information system, it was not possible to assess energy inputs in different Slovene regions or on the level of the whole country, in which private forests comprise 74% of forested areas (SLOVENIAN FOREST SERVICE 2007). The estimation was drawn in a model research area in order to comprehend differences between preserved and changed forests and to prepare a model of landscape function based on energy flows.

The meaning of suburban forests and their conservation was assessed separately, based on the spatial model of landscape structure in Slovenia. In view of the expected changes, driven partly by agricultural policy, but also by the increasing urbanisation pressures , the spatial model may indicate developmental possibilities at the level of Slovenian macroregions.

In this study, the objective of the spatial model at the national level, designed in the GIS environment, was to demonstrate the application of landscape ecological reference points for an assessment of landscape structure in the open space of Slovenian settlements.

MATERIAL AND METHODS
MATERIALI IN METODE

Our research was designed on two level-approach – a model of landscape types for a whole country, and a study of forest landscape functioning based on an energy input into forests in the municipality of Kočevje with an emphasis on forest within 1 km distance belt of the town of Kočevje. 1 km distance or 15 minutes walking distance is often regarded as a potential influence zone of a daily recreation (ARNBERGER 2006) or potential urban catchment area (VAN HERZELE 2005).

In our study, a model of landscape types was designed based on similar research of landscape structure in Slovenia (HLADNIK 2005). At the national level, an assessment of the landscape structure has been carried out on the basis of maps of Slovenian forests, data on the land cover in Slovenia assessed as part of the CORINE land cover project, data on the boundaries of the cadastral municipalities in Slovenia, and an assessment of forest cover in the country at the end of the19th century. The cadastral municipality was defined as the smallest spatial unit and, for the individual cadastral municipalities the tree cover was assessed from the data provided by the raster maps of Slovenian forests on a scale of 1:50,000. These data were compared with the map of forest cover at the end of the 19th century to assess the core of the primary forest in Slovenia and the landscape changes at the regional level. The cadastral municipalities where the present forest cover was less than 40% were classified into the landscape type agricultural and urban landscape, while the municipalities with between 40 and 85% forest cover were classified into the forested landscape type . The municipalities in which the present forest cover is greater than 85% and lie in the core area of primary forest were classified as forest landscapes, as proposed by Hladnik (2005).

For an assessment of the present forest borders and forest structure, digital data derived from a map of Slovenian forests on a scale of 1:5,000 (SLOVENIAN FOREST SERVICE 2007) were used. The data were processed using the IDRISI and ArcGIS geographic information system. The proximity of Slovenian urban settlements to forest borders was assessed on the raster map of forest and non-forest land, based on the distances between the forest border and the borders of the settlements presented on the CORINE land cover map. These distances were classified according to distance belts in order to determine the position of settlements in the landscape matrix. Regarding their spatial extent, the settlements on the CORINE land cover map were arranged into four size classes (Fig. 2): smaller than 50 ha, 50 to 99 ha, 100 to 249 ha, and those extending over more than 250 ha large area.

At the end we assessed the percentage of forest cover and the share of preserved forests in the 500 m distance belt from the city borders. We have followed the idea that the relatively natural forests support a broader spectrum of social human needs than those that have been highly modified (i.e. spruce monocultures). According to the Slovenian Forest Practice Rules (MKGP 1998), the conservation status of forest stands is divided into four groups: non-indigenous tree species on the site representing less than 30% of the growing stock (1), 31–70 % (2), 71–90 % (3), and more than 90 % (4).

Hanewinkel (2002) showed that the actual amount of empirical data available for comparing different forest management systems at the regional level is small. He proposed a benchmarking approach to reveal best practices in forest management systems. Slovenian forestry, on the other hand, has developed forest management planning for all forests regardless ownership. Forests were classified into management classes based on natural characteristics. A forest management class consists of forests with similar potential vegetation, similar structure and development trends and a common management goal regarding various forest functions. Due to such planning concept, it is possible to trace evidences of different production, silviculture and protection measures for different forest management classes and therefore to evaluate energy inputs needed for forest management.

The first study of artificial energy flows was based on the method carried out by Pirnat (1999) in the Kočevje region (762 km^2), which is one of the most typical forest landscapes in Slovenia. The vegetation mainly consists of different forms of Dinaric silver fir - beech forests. There are also different beech and oak communities, highly productive silver fir forests on acid soils, as well as sites with valuable broad-leaved species and, finally, some pine forests. At present, almost a quarter of forests in the region have a significantly modified natural tree species composition. Most of these sites have an artificial dominance of Norway spruce and require a high investment in both materials and energy to become highly productive.

Pirnat (1999) compared forests according to the structure of annually introduced artificial energy, i.e. human labour and machine work, energy input contained in materials, such as fertilisers, seeds, and protective substances (ZUCCHETTO / JANSSON 1985). Data on forest production were based on subsidies for forest work, including both silvicultural and protective measures carried out in the research period of one year, the costs of fuel and lubricants, as well as subsidies for spare parts and depreciation of machinery. In addition, the activities requiring human labour and machine work were taken into account. Manual labour required for protective measures was also considered. Because felling and silvicultural measures are not carried out every year in the same area, the work in a study area was converted to the whole forest area, that is, including areas in which these measures were not performed in that year. This made it possible to balance out the differences in forestry inputs. For each activity, the number of hours performed by individual machines in a certain area was multiplied by their capacity to obtain values in kWh (PIRNAT 1999). The costs of fuel and lubricants, expressed in monetary units, were converted into kWh in order to divide the price by the general price of crude oil in the study period. The energy value of crude oil is 43 MJ/kg on average, the density being 0.8 kg/dm^3 (SMIL 1991), thus the energy value of a litre of crude oil is about 9.55 kWh. The same method was also used to estimate some other costs (spare parts, depreciation of machinery, construction works in forests). For material inputs, energy values from the literature were used (SMIL 1991).

According to the described methodology, the same energy input information was extrapolated to the different forest management classes at a distance of 1 km around the town of Kočevje in 2007 (Table 1).

From the multifunctionality point of view, the 1 km belt around Kočevje is regarded as most appropriate to cover forests that are important for wood production and at the same time significant for other non-timber functions that are extremely important for health and well-being of the local citizens (COST E39). At the same time, the same area is covered by highly changed forests (spruce monocultures) that have turned out to be most sensitive to bark beetles in recent years.

RESULTS AND DISCUSSION
REZULTATI IN RAZPRAVA

According to the Slovenian Forest Service, forests cover 58% of the country, whereas forested and forest landscape account for 72% of the national area (HLADNIK 2005). Much of the former agricultural land has reverted to forest especially in western and central Slovenia to the extent that national forest cover has increased significantly (20%) over the last 200 years. The modernisation of agricultural production and modification of the life style in the countryside have generated homogeneous, ecologically and visually impoverished agricultural landscapes in the plains, because mainly hilly areas were abandoned and left to succession (OGRIN 2002).

Nowadays, Pomurje is the sole macro-region in which agricultural landscapes still prevail (Fig. 1), with farmland covering 68% and forests 27%. As elsewhere in Europe, forests, together with hedgerows and remnants of the former natural vegetation, sustain natural processes on agricultural land and contribute to human well-being by providing natural restorative spaces. In view of the expected changes, driven partly by agricultural policy but also by increasing urbanisation pressures , the spatial model may indicate developmental possibilities at the level of Slovenian macro-regions.

Most of the Slovenian urban settlements are surrounded by forests within walking distance (< 1 km); even for the largest cities, such as Ljubljana, Maribor and Celje, the distance between residential areas and nearby forests is less than 1 km. Settlements were classified into the group of cities further away from forests (Fig. 2), as some parts of residential areas (< 25 % of the total area) are located more than 1 km from the forest edge.

There is a regional variation in the landscape structure and forest conditions in the eight Slovenian macro-regions. The Mura and Drava River macro-regions feature a different distance pattern and the percentage of preserved forests surrounding urban settlements (Fig. 3). These are the macro-regions where agricultural landscapes still prevail today. In other

Table 1: Distribution of different forest management classes within a 1 km belt around the town of Kočevje

Preglednica 1: Razpored različnih gozdnogospodarskih razredov znotraj 1 km pasu okrog mesta Kočevje

Forest management class / *Gozdnogospodarski razred*	Preserved *Ohranjeni*		Changed *Spremenjeni*		Total (ha) *Skupaj*
Fir-beech lowland forests / *Jelovo-bukovi nižinski sestoji*	0.00	0.00	0.00	9.58	9.58
Lowland forests – dominance of spruce / *Nižinski zasmrečeni sestoji*	0.00	0.00	15.24	242.08	257.32
Fir-beech forests – dominance of spruce / *Jelovo-bukovi zasmrečeni*	0.00	67.13	6.81	118.03	191.97
Low-yield forests / *Malodonosni sestoji*	0.00	0.00	0.67	0.00	0.67
Fir-beech forests / Jelovo-bukovi sestoji	119.81	23.41	0.00	0.00	143.22
Oak-beech forests / *Hrastovo-bukovi sestoji*	16,71	1.78	1.08	15.43	35.00
Beech forests / *Bukovi sestoji*	4.43	21.12	0.00	0.00	25.55
Preferential areas for game / *Prednostne površine za divjad*	0.00	0.00	14.41	0.03	14.44
Forests reserves / *Gozdni rezervati*	3.19	0.00	7.82	0.00	11.01
Total area (ha) / *Skupaj (ha)*	144.14	113.44	46.03	385.15	688.76

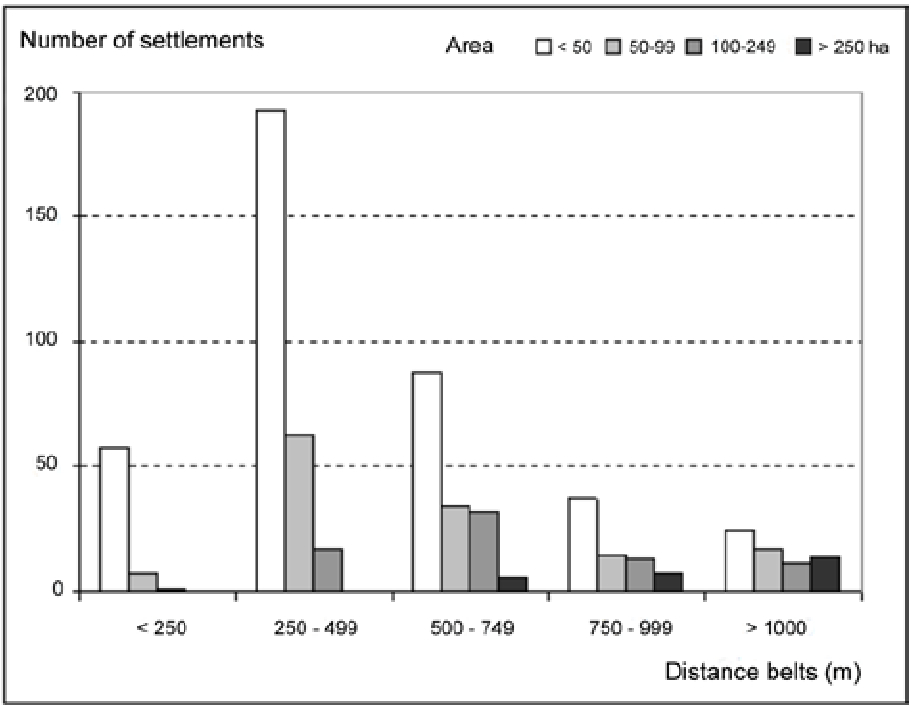

Fig. 2: The distribution of Slovenian settlements categorized in four groups of surface area in hectares and their position in the landscape matrix, defined by distance belts from the forest edges (According to the CORINE Land Cover map and the Slovenian Forest Service Forest map).

Slika 2: Razpored slovenskih mest, razporejenih v štirih velikostnih skupinah (v ha), in njihov položaj v krajinska matici, opredeljen z razdaljami od gozdnega roba (v skladu z masko CORINE Land Cover in masko gozdov Zavoda za gozdove Slovenije).

macro-regions, forests and remnants of forest landscapes prevail. The most extensive type in Slovenia is the forested landscape, in which forest cover is estimated to be between 40 and 60% (HLADNIK 2005). In these areas, the urban settlements are located in the forested landscapes, where forests predominate even in a close proximity of 500 m from the edge of the city (Fig. 3).

The region of Kočevsko (Fig. 1) is the largest forest-dominated meso-region in Slovenia and therefore ideal for studying landscapes where forests are the predominant land use, offering contrasting possibilities of social and natural functions. Therefore, a detailed investigation of different forest types has been carried out within 1 km distance around the town of Kočevje. The results show significant distribution of

Table 2: Machine work with spare parts, depreciation in forest production as an annual energy input in different management class forest stands (adapted from PIRNAT 1999)

Preglednica 2: Strojno delo, rezervni deli, amortizacija v gozdni proizvodnji kot letni energijski vnos v gozdovih različnih gospodarskih razredov (prirejeno po PIRNAT 1999)

Management class / *Gospodarski razred*	Forest production measures (in kWh/ha/year) *Ukrepi pri gozdni proizvodnji (v kWh/ha/leto)*				
Oak-beech forests / *Hrastovo-bukovi sestoji*					505.5
Beech forests / *Bukovi sestoji*					503.4
Fir-beech forests with dominance of spruce / *Jelovo-bukovi zasmrečeni*					502.1
Fir-beech lowland forests / *Jelovo-bukovi nižinski*				483.6	
Fir-beech preserved forests / *Jelovo-bukovi ohranjeni*				435.7	
Lowland forests with dominance of spruce / *Nižinski zasmrečeni sestoji*			393.8		
Preferential areas for game / *Prednostne površine za divjad*		216.7			
Low-yield forests / *Malodonosni sestoji*	170.7				
Protection forests / *Varovalni gozdovi*	107.2				

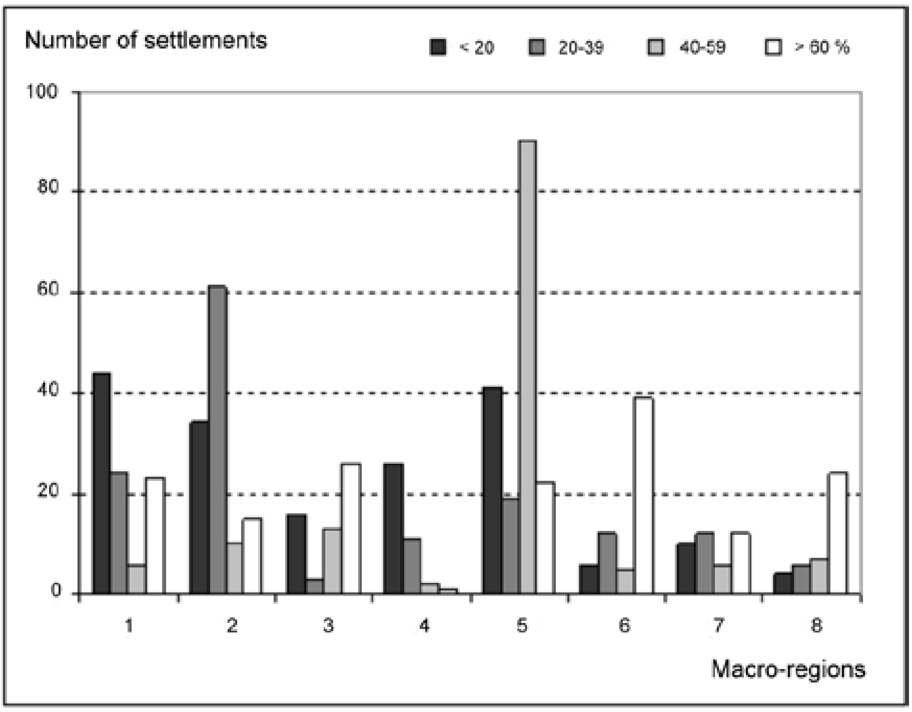

Fig. 3: The distribution of settlements in eight Slovenian macro-regions according to the percentage of the surface of preserved forests within a 500 m distance belt from the city borders.

Slika 3: Razpored naselij v osmih slovenskih makro regijah glede na odstotek površine ohranjenih gozdov, ki ležijo v pasu znotraj 500 m razdalje od roba mest.

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8 *Južna Primorska* - Southern Littoral

different management types, although 65% of all forests belong to those with dominance of spruce.

Pirnat has found out (1999) that average artificial energy inputs amounted to 2400 kWh/ha/year in forested areas. Machine work and human labour needed for felling and skidding, silvicultural and protective measures, including depreciation of machinery and spare parts, in managed forests accounted for less than 28% of all energy inputs, whereas the costs of construction and maintenance of forest roads accounted for 71%, and material inputs for only about 1% of them. The same information has been used in 2007 for the evaluation of different artificial energy inputs in urban forests. We have evaluated energy inputs in forestry production, silviculture and protection measures of different forest types within 1 km distance around the town of Kočevje. The lowest energy inputs occurred in less intensively managed forests, particularly thermophilic European beech forests, and in forests with low productivity with around 100 kWh/ha. In differently intensive management forest classes, however, the artificial energy input was already higher, ranking from nearly 400 to 500 kWh/ha annually. There was not so much difference between different management classes, for more or less same technical and machinery was widely used. Differences in energy input for production are mostly a result of various rocky terrains than anything else (Table 2).

However, when only the costs of silvicultural and protective measures are compared, that is direct inputs into different forest areas, major differences appeared in energy inputs between management classes. Annual artificial energy inputs of machine work for silvicultural measures were ranking between zero (where no work has been done) to up to 28 kWh/ha particularly in high in low-yield stands due to energy inputs in the form of material inputs such as planting.

Annual energy inputs for protection measures were, on average, about three times higher than for silvicultural measures, ranking from zero to up to 56 kWh/ha. Their internal structure was also different, since they required practically no machine work. All the costs are due to material inputs such as

Table 3: Machine and manual work and material inputs in the form of silvicultural and protective measures as an annual energy input in different management class forest stands (adapted from PIRNAT 1999)

Preglednica 3: Strojno in ročno delo ter snovni vnosi za gojitvena in varstvena dela kot letni energijski vnos v gozdovih različnih gospodarskih razredov (prirejeno po PIRNAT 1999)

Management class *Gospodarski razred*	Silvicultural measures (in kWh/ha/year) *Gojitvena dela (v kWh/ha/leto)*				Protection measures (in kWh/ha/year) *Varstvena dela (v kWh/ha/leto)*				
Fir-beech lowland forests *Jelovo-bukovi nižinski*			7.1					48.6	55.7
Lowland forests with dominance of spruce / *Nižinski zasmrečeni sestoji*			6.4					49.0	55.4
Fir-beech forests with dominance of spruce / *Jelovo-bukovi zasmrečeni*			9.9					35.3	45.2
Low-yield forests *Malodonosni sestoji*				27.8		17.4			45.2
Fir-beech preserved forests *Jelovo-bukovi ohranjeni*			5.7			11.1			16.8
Oak-beech forests *Hrastovo-bukovi sestoji*			12.0		4.6				16.6
Beech forests *Bukovi sestoji*		4.3				11.8			16.1
Preferential areas for game *Prednostne površine za divjad*	0.1					12.1			12.2
Protection forests *Varovalni gozdovi*	0				0				0

repellents, pheromones, and fences. Measures requiring the most energy were carried out in forests in which their natural composition has been modified, specifically the forests dominated by Norway spruce, which required the highest energy inputs for protection (Table 3).

CONCLUSIONS
ZAKLJUČKI

Human interference into structure and processes of natural ecosystems has produced several negative impacts, which are nowadays manifested in different forms. One of them is a need of extra artificial material and energy inputs needed to maintain changed productive forest ecosystems. In several recent studies, the economics and strategies of transformation to continuous cover forestry were investigated (JACOBSEN *et al*. 2004; ANDREASSEN / ØYEN 2002; PRICE / PRICE 2006). Hanewinkel (2002) stressed in his literature review that almost every study shows that uneven-aged forests yield higher net revenues than comparable even-aged forests, but in his model study, assuming the same timber quality, the most favourable variants of both forest systems yielded almost the same revenues. The most important influence on the results in the even-aged model was the level of risk.

Recent increase of forests in many EU countries is a result of national policies and afforestation activities. However, this information alone is not enough to evaluate the quality of a landscape. In the case of vulnerable species, such as Norway spruce, it may even cause additional problems on a landscape level especially in urban forests, where multifunctionality and forest stand stability have gained high priority (COST E39). In the countries with high percentage of forests and good natural regeneration possibilities, the main question in the future is not how much more forest is needed, but rather how to maintain its stability.

Lowland forests dominated by Norway spruce (*Picea abies* (L.) Karsten), which require relatively higher amounts of direct artificial energy inputs annually especially as silvicultural and protective measures, account for 14% of the study area and 8% of the broader region of Kočevje. It is typical that they include land closest to farms and settlements along the valleys, which also explains why they have been so highly modified by historical management practices. In recent years (2005 - 2007), these forest have suffered seriously from bark-beetle attack (Figure 4). Several hundred hectares had to be cut and planted with trees.

Forestry is therefore facing a serious problem. Especially forests with dominance of spruce require high energy inputs for maintenance and protection on the one hand and are at the same time under pressure of urban needs for multifunctionality at the same level as close to nature beech stands.

Multifunctional forest management as declared in the Rural Development Programme of Slovenia (MKGP, 2007) will have to be adapted to the different natural and socio-econo-


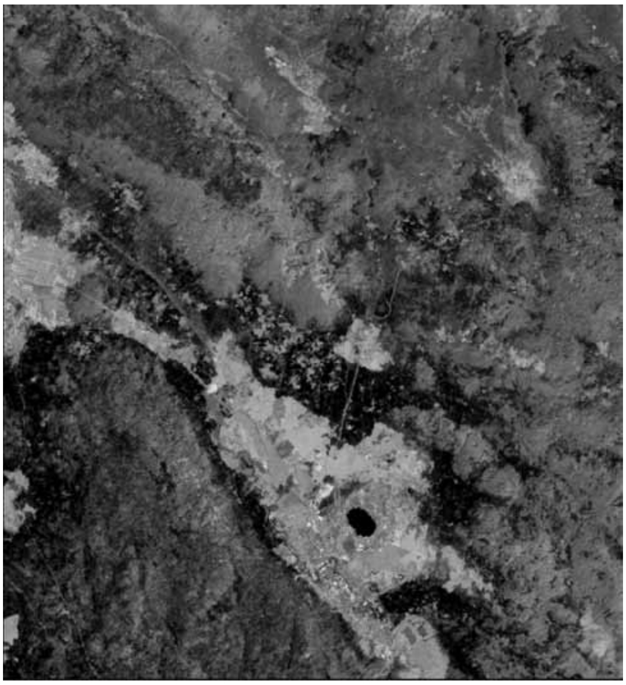

Fig. 4: The appearance of forests near the town of Kočevje in the years 2000 (left) and 2005 (right). Note the changes in the areas of spruce monocultures, visible on Landsat TM images (TM bands 4,5,3).

Slika 4: Videz gozdov v okolici mesta Kočevje v letih 2000 (levo) in 2005 (desno). Na satelitskih posnetkih satelita Landsat (TM bands 4,5,3) so vidne spremembe v smrekovih monokulturah.

mic situations, characteristic of each Slovenian region. However, only those forests that are close to a natural state with relatively low associated energy inputs, can be regarded in the long term as stable. Such forests will be able to fulfil the demands of the expanding urban population under different levels of environmental stress. The concept of multifunctionality will have to highlight the importance of preserved natural ecosystems in the sphere of cultural landscapes, not just in the remote areas but even more in urban and suburban places.

In some countries, the distance between residential areas and nearby forests is to a large extent an urban planning problem, although other uses of the forest environment may account for the non-timber values of forests as well (HOERNSTEN / FREDMAN 2000). This is especially likely to apply to Slovenia - a country with almost 60% forest cover and a legal right of common access to the natural environment. In such situation, the border between the urban and suburban is not clear and in the light of new proposal such as porous landscapes (BUSCK *et al.* 2008) not really necessary.

In the light of global climate change, one of the crucial questions is how much energy and what type of energy and material should a sustainable society consume. As for the forestry, the same question can be applied: how much energy is needed for the maintenance of different changed forest stands in the light of ecosystem services (production, cultural, preservation) demanded by urban society. The differences in the amount and type of artificial energy inputs needed for the maintenance protection in changed forests in comparison with the measures needed in natural forests can be regarded as a measurable indicator for sustainable forestry nowadays and in the future.

POVZETEK

Kljub temu da v 20. stoletju številni avtorji zaznavajo grožnje zaradi sprememb v tradicionalni kulturni krajni, pa se je le malo avtorjev poglobilo v vloge gozdov v tem procesu, čeravno prav gozdovi marsikje v Evropi predstavljajo krajinsko matico. Čeprav se je površina gozdov marsikje v Evropi konec 20. stoletja celo povečevala, to še ne pomeni, da se je ob tem povečala stabilnost krajine. Zlasti predeli z zasmrečenimi gozdovi so v preteklosti doživeli številne resne motnje marsikje po Evropi (SCHELHAAS *et al*. 2003, LARSEN 1995, TEUFFEL *et al*. 2004). Zasmrečeni gozdovi ležijo pogosto v bližini mest in so lahko kljub spremenjeni zgradbi zanimivi za obiskovalce, ki skušajo v njih poiskati prostor, v katerem bi se znebili stresa, ki izhaja iz sodobnega urbanega načina življenja (COST E39 2007).

Po Plutu (1999) je smiselno deliti Slovenijo na osem makroregij in 25 mezoregij (slika 1). Za vsako izmed regij je mogoče izdelati tudi prostorski model zgradbe gozdov, v našem primeru nas je zanimala prostorska zgradba zasmrečenih nižinskih gozdov, ki ležijo v bližini urbanih središč.

Raziskavo smo zasnovali dvostopenjsko – model razmestitve ohranjenih gozdov v različnih krajinskih tipih smo izpeljali za vso Slovenijo, model delovanja gozdne krajine z vidika umetnih energijskih vnosov pa smo preskusili v gozdovih, ki ležijo znotraj 1 km pasu okrog mesta Kočevje, saj je po mnenju številni avtorjev 1 km razdalja oziroma 15 minut hoje v eno smer najbolj pogosta cona za dnevno rekreacijo. Zanimalo nas je, kakšna je povezava med različnimi gozdarskimi aktivnostmi (proizvodnja, gojenje gozdov, varstvo gozdov) in za to potrebnimi umetnimi energijskimi vnosi v gozdovih različnih gospodarskih razredov.

Model krajinskih tipov smo metodološko zasnovali po predhodni raziskavi (HLADNIK 2005), ki je zajemala v okolju GIS podatke o današnji rabi tal po projektu CORINE, ohranjenosti gozdov danes in podatke o gozdovih po katastrskih občinah na podlagi Franciscejskega katastra. Tako smo pridobili podatke o krajinskih tipih (gozdna, gozdnata, kmetijska in urban krajina), gozdnih površinah in jedrih stabilnih gozdnih površin v Sloveniji. Vse prostorske analize smo izpeljali v okolju geografskih informacijskih sistemov IDRISI in ArcGIS. V tem okolju smo tudi izračunali razdalje med gozdovi in naselji ter deleže vseh in ohranjenih oziroma spremenjenih gozdov, ki so ležali znotraj kilometrskega pasu mest.

Gozdna in gozdnata krajina zavzemata 72 % Slovenije (HLADNIK 2005). Pomurje je danes edina regija, kjer še prevladuje agrarna krajina. Večino slovenskih mest obdajajo gozdovi na razdalji, ki je krajša od enega kilometra. Na podlagi prostorskega modela krajinske zgradbe in podatkov gozdarskega informacijskega sistema smo med slovenskimi regijami ocenili razlike v deležu ohranjenosti primestnih gozdov.

Kočevsko je regija z najvišjo gozdnatostjo in z zelo različnimi gozdovi, zato smo podrobno raziskavo izpeljali prav za gozdove, ki ležijo znotraj kilometrskega pasu mesta Kočevje. V tem pasu je kar 65 % gozdov sodilo v kategorijo zasmrečenih gozdov.

Za analizo umetnih energijskih vnosov smo izhajali iz predhodne raziskave z metodo, ki jo je uporabil Pirnat (1999), po kateri so bili zasnovani in izmerjeni vsi letni umetni energijski vnosi (strojno in ročno delo, vnosi materialov, sadik, poraba goriva in maziva) po posameznih gospodarskih razredih. Te podatke smo priredili in uporabili za oceno letnih energijskih vlaganj v gozdove, ki ležijo znotraj kilometrskega pasu mesta Kočevje (preglednica 1), ki so zaradi bližine mesta zanimivi tudi za rekreacijo.

Na višino umetnih energijskih vlaganj v gozdni proizvodnji vplivajo bolj naravni geomorfološki dejavniki (relief, razdalja) kot zgradba gozda, bistvene razlike pa se pojavijo pri oceni vlaganj v gojenje in varstvo gozdov. Kot prikazujemo v preglednici 3, so umetni energijski vnosi pri gojenju gozdov nihali od 0 do 28 kWh/ha letno, še posebej, če je na določeni površini potekala sadnja. Še višji so umetni energijski vnosi v varstvo gozdov, ki so bili v povprečju do trikrat višji kot tisti, potrebni za gojenje, in so nihali med 0 in 56 kWh/ha letno. Med snovne vnose v varstvo gozdov sodijo različne zaščite, od feromonov, premazov do ograj. Značilno je, da je bilo največ vnosov potrebnih v zasmrečenih gozdovih (preglednica 3), ki pa hkrati ležijo mestu Kočevje najbližje, v letih 2005 – 2007 pa so bili resno poškodovani zaradi napadov podlubnikov.

Z raziskavo pritrjujemo številnim evropskim raziskovalcem, ki ugotavljajo, da bo treba gozdove s spremenjeno drevesno sestavo popeljati v sonaravno zgradbo. Hkrati se iz izkušenj v različnih primestnih gozdovih Evrope (COST E 39 2007) lahko učimo, da je ob ukrepanju treba dosledno upoštevati njihovo resnično večnamensko rabo ter stabilnost (in varnost) in ne le ekonomskih kazalcev, čeprav smo z našo raziskavo opozorili tudi na stroškovni vidik – zasmrečeni gozdovi bodo še dolgo zahtevali pogosta in energijsko bolj zahtevna vlaganja kot ohranjeni mešani sestoji. Hkrati se je izkazalo, da so nizki energijski vnosi zlasti v gojenje in varstvo gozdov eden izmed temeljev, na katerih lahko utemeljujemo stabilnost gozdov.

V številnih državah je morda vsebinska razlika med (pri) mestnim gozdom in drugimi gozdovi pomembna zlasti za prostorske planerje, pri nas pa je zaradi majhnih razdalj od mest do gozdov in posledično naraščajočega urbanega pritiska na vedno večje površine gozdov to tudi upravičeno vprašanje za razvoj večnamenskega gospodarjenja gozdarske stroke. Morda je čas, da se v luči napovedanih klimatskih sprememb vprašamo, koliko in kakšno energijo potrebujemo za vzdrževanje naših gozdov. Razlike v vrsti in višini umetnih energijskih vnosov so lahko eden izmed merljivih kazalnikov trajnostnega gozdarstva.

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