NATURAL AND ARTIFICIAL ENERGY FLOWS IN FOREST AND AGRICULTURAL LANDSCAPES OF KOČEVSKO

NARAVNI IN UMETNI ENERGIJSKI TOKOVI V GOZDNIH IN KMETIJSKIH EKOSISTEMIH KOČEVSKE

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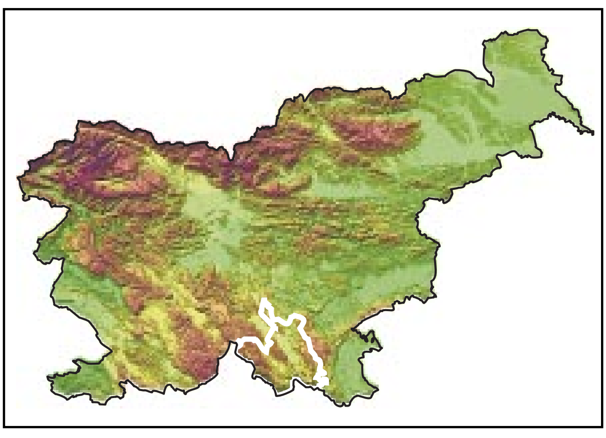
Virgin forest Rajhenavski rog (photography Jerneja Fridl).
Pragozd Rajhenavski rog (fotografija Jerneja Fridl).



Abstract UDC: 913(497.4 Kočevska):620.9
620.9:504(497.4 Kočevska)
COBISS: 1.01

Natural and Artificial Energy Flows in Forest and Agricultural Landscapes of Kočevsko

KEY WORDS: energy flows, natural energy inputs, artificial eneregy inputs, cultural landscape, Kočevska

The cultural landscape is characterized by different proportions of natural and artificial energy inputs. The article compares energy flows in agricultural ecosystems and forests. The study site was in the Kočevje region in the sample year 1993. The broader research area covered 762 km^2 of the former Municipality of Kočevje, while a detailed investigation was carried out in a sample area of 353 km^2. The aim of the study was to examine natural energy input, specifically incoming solar radiation, and artificial energy inputs that include human labour and machine work, spare parts, depreciation of machinery, and material input as forms of energy input. Natural energy input amounts to between 1095 kWh/m^2 per year (forests) and 1120 kWh/m^2 per year (agricultural ecosystems). Artificial energy inputs account for 0.2–1.1‰ of incoming solar energy. The relatively highest artificial energy inputs were introduced on cultivated fields with 1.26 kWh/m^2, followed by meadows with 0.67 kWh/m^2, pastures with 0.45 kWh/m^2, and managed forests with an average of 0.24 kWh/m^2. Intensively managed forests received the highest amount of artificial energy inputs, that is 0.25–0.255 kWh/m^2. Thermophilic forests and forests with low site productivity received the lowest amount of artificial energy inputs, 0.21–0.23 kWh/m^2. Areas regenerated from abandoned farmland, areas covered with shrubs, and forests that are not managed function with incoming solar energy only.

Izvleček UDK: 913(497.4 Kočevska):620.9
620.9:504(497.4 Kočevska)
COBISS: 1.01

Naravni in umetni energijski tokovi v gozdnih in kmetijskih ekosistemih Kočevske

KLJUČNE BESEDE: pretoki energije, vnos naravne energije, vnos umetne energije, kulturna pokrajina, Kočevska

Razmerja med naravno prispelimi in umetno vnesenimi energijskimi tokovi se značilno razlikujejo med različnimi ekosistemi v kulturni krajini. V pričujočem članku smo primerjali energijske tokove v kmetijskih ekosistemih in gozdovih na Kočevskem, v vzorčnem letu 1993. Naravno prispelo energijo daje sončno obsevanje, umetno vneseno pa strojno in ročno delo, rezervni deli in amortizacija ter snovni vnosi, ki smo jih obravnavali kot energijo. Naravni globalni energijski vhodi dosegajo letno okrog med 1095 kWh/m^2 (gozdovi) do 1120 kWh/m^2 (kmetijski ekosistemi). Umetni energijski vhodi dosegajo od 0,2–1,1 ‰ prispele sončne energije. Relativno največ umetne energije so vložili v njive, 1,26 kWh/m^2, v travnike 0,67 kWh/m^2, v pašnike 0,45 kWh/m^2 in v gospodarske gozdove v povprečju 0,24 kWh/m^2. Intenzivno gospodarjeni gozdovi prejeli največ umetno vnesene energije, in sicer od 0,25–0,255 kWh/m^2, najmanjše vložke so dobili manj intenzivno gospodarjeni termofilni in malodonosni gozdovi, in sicer od 0,21–0,23 kWh/m^2 letno. Zaraščajoče se površine in negospodarski gozdovi so delovali samo z naravno prispelo energijo.

The editorialship received this paper for publishing in June 2nd 1999.
Prispevek je prispel v uredništvo 2. 6. 1999.

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1. Introduction

The Kočevsko region lies in the southern part of Slovenia and covers an area of 600 square kilometers. Geologically it is characterized by limestone and dolomite, vegetationally by extensive areas of fir and beech forest, and socially and economically by few scattered settlements around the town of Kočevje. Forestry and agriculture are the most important land uses in the area.

Since primeval times, humans have managed, by using manual and animal labour, to transform the earth into a cultural landscape. This has made possible the survival of mankind, the constant improvement of the settlement culture, and spiritual development. The period prior to the Industrial Revolution was characterized by the relatively slow growth of energy use. The Industrial Revolution marked the beginning of the gradual use of stored fossil energy. The utilization of this energy led to the swift progress of mankind, along with the formation of a number of artificial systems such as factories, towns, and infrastructure, all of which today form the very basis of modern society.

Odum (1989) distinguishes between (a) natural, (b) domesticated, and (c) artificial environments in the present day. Each of these is characterized by a different internal ratio between incoming natural and introduced artificial energy flows.

(a) Natural environments are dependent on solar energy and its indirect forms such as winds, water flow, rainfall, and gravity. Natural forests that are not managed also belong in this category.
(b) Domesticated environments are partly dependent on incoming solar energy and partly on energy introduced into the system in the form of human and animal labour, machine work, and introduced materials such as pesticides, seeds, and fertilizers. Such environments – managed forests and agricultural land – occupy the greater part of our planet.
(c) Artificial environments today include cities and industrial centers with infrastructure. They operate, directly or indirectly, with fossil energy. They develop the fastest of all and also represent the greatest users of artificial energy inputs (Odum 1989).

The first two environments are defined by Odum as life-supporting systems, since food is produced there and plants use solar energy via photosynthesis to produce phytomass. They control water and air flows and influence mineral cycles.

The basic landscape ecological terms and the basic data on the Kočevsko region are taken from Slovene and foreign literature (Anko 1986, Ciglar 1979, Forman 1995, Naveh, Lieberman 1994, Naveh 1994, Puncer 1980, Zonneveld 1995)

The site of the research on energy flows is the Kočevje region. The landscape here is an open system in terms of matter and energy where the flows and boundaries of impacts of matter and energy are human-induced. Thus, humans exert a crucial influence on the capacity for a certain self-regulation of its ecosystems. Administrative borders most clearly show the boundaries of the cultural landscape, forming the most logical framework for research on the cultural landscape. The study therefore investigated the Kočevje region that encompasses the 1993 area of the Municipality of Kočevje.

The flows of matter and energy were studied to determine changes in the quality of the landscape. The ecological classification of the landscape followed the scheme for the structure and functioning of the landscape developed by Anko (1986). In addition, those changes in the landscape were taken into account that indicated changes in any constituent of the structure and functioning of the landscape.

The aim of the study was:

- to determine the structural characteristics of the landscape under consideration,
- to determine the form and category of natural and artificial energy flows at the level of the landscape where a forest matrix with patches of agricultural use dominates,

- to identify ecosystems in the landscape in which individual forms of energy input occur, in which natural energy flows dominate, in which artificial inputs dominate, and in which both forms of energy input are represented along with the relationship between the two,
- to determine the link between external signs of changes in individual ecosystems and the various proportions of introduced artificial energy typical of them,

The aim of the study was also to verify the following hypotheses:

- The significant factors that help us understand a landscape are its structure, its functioning, and the changes occurring in it. For all three factors, the relationship between natural and social factors is of significance, the latter being the more important factors that affect the changes in the cultural landscape.
- Previously, the Kočevje region was largely formed by artificial energy inputs in the form of human labour, whereas today the region has been affected by changes resulting from the input of new forms of artificial energy in the last half century. The present landscape structure is a result of the current relationship between natural conditions and land use. Its future depends on human input in the selected land use.
- Knowledge of energy flows among ecosystems linking the landscape into a functional whole is the key factor in the internal categorization of the landscape into different types of ecosystems. In this case, these are groups of ecosystems with similar energy flows. The homogeneity was investigated from the viewpoint of fundamental ecological laws (structure, functioning, ratio between natural incoming and introduced artificial energy, biomass produced in agricultural ecosystems, and biomass produced and maintained in the forest).
- Managed forests differ according to the ratio between natural incoming and artificial introduced energy.
- Managed forests and agricultural land also differ with regard to fluctuations in energy input or place of input (in forests also according to their developmental phase).

2. Methods

Forests and agricultural land were compared according to:

- the quantity of organic matter,
- the ratio between natural incoming and introduced artificial energy, and
- the structure of introduced artificial energy (human labour and machine work, energy input contained in materials such as fertilizers, seeds, pesticides, and protective repellent substances).

The study was based on the following two starting points. The Kočevje region is an extensive landscape unit; therefore, the available funds and time did not allow us to investigate the entire region with the same accuracy. Thus, general conditions of the area and data on natural incoming energy were dealt with for the whole Municipality of Kočevje, encompassing 762 km^2. Artificial energy inputs, however, were analyzed in detail only in some selected parts due to the extensive work involved, and the findings were extrapolated for the rest of the area. The sample area covers 353 km^2 or 46% of the former Municipality of Kočevje. Forested land investigated in the study consists of individual forest subcompartments in the management units. These are typical management units of the present-day Kočevje region. For the agricultural land considered in the study, all three state-owned farms situated in the area managed by MKG Kočevje were considered as sample agricultural land. The data on all energy inputs was compared for the sample year 1993.

The first part of the study concerns the energy evaluation of incoming natural energy flows, primarily solar energy. This was calculated for the purposes of the study by the Geography Institute of the Scientific Research Center, Slovene Academy of Sciences and Arts, using the *Sonce* computer program (Gabrovec 1996). This program employs formulae for direct and diffuse radiation developed by Hočevar and his associates (1980). All the calculations were done for one-hour intervals at the Novi Lazi weather station near Kočevje (Hočevar 1980). Slope and aspect data are taken from the Slovene Digital Elevation Model 100.

Other data on the area was converted first to vector form and then processed using the ROOTS 1.0 program (Corson-Rikert 1992). This data included the social plan for land use in the Kočevje region for the period 1981–1985 on a 1 : 50,000-scale map; 1 : 200,000-scale geological, phytocoenological, and pedological maps of the Kočevje region; the precipitation chart of the Kočevje region; and the 1 : 28,800-scale charts of measurements done in the Kočevje region during the time of Emperor Joseph II that formed part of the *Emperor Joseph II Land Survey* of the Austrian Empire (Rajšp 1996). All the comparisons in terms of content and land cover were processed using the GIS created using IDRISI 4.1 (Eastman 1933), calculations and tables were done with the EXCEL 5.0 program using Microsoft Windows, and the maps were drawn with the COREL DRAW 5.0 program.

The statistics for artificial energy inputs and production on agricultural land for the year 1993 are from MKG Kočevje and for forests from GG Kočevje and the Forest Service of Slovenia. Historical data on the socioeconomic development of the region and basic data on its natural features are from the literature. The data on forest production is based on the subsidies for forest work and silvicultural and protective measures carried out in 1993. This data indicates the proportion of the costs of fuel and lubricants on one hand and of subsidies for spare parts and the depreciation of machinery on the other. As to silvicultural measures, those were taken into account that require human labour and machine work. 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 measures taken in a given area were calculated for the whole forest area, that is, for the areas where these measures were not performed that year. This made it possible for us not only to compare forestry inputs with agricultural inputs but also to balance out the differences in forestry inputs.

For agricultural land, the situation is different. The data refers to the utilization of all areas in 1993, with differences between individual areas depending as well on individual crops. Here the data on introduced fuel and lubricants were used on one hand and subsidies for spare parts and depreciation of machinery on the other. Manual labour and machine work were also taken into account.

For each type of land use, the total number of hours of operation by individual machines in a certain area was multiplied by their capacity to obtain values in kWh. The costs of fuel and lubricants, expressed in SIT, were converted into kWh, so that the price was divided by the prevailing price of crude oil in 1993 (52.73 SIT per liter). The energy value of crude oil is between 42 and 44 MJ/kg, that is, 43 MJ/kg on average, its density being 0.8 kg/dm^3 (Smil 1991, Anko 1985). The energy value of a liter of crude oil is therefore about 9.55 kWh. The same method was also used to estimate some other costs (spare parts, depreciation of machinery, construction work in the forests). For material inputs, energy values from the literature were used (Leskošek 1993, McDonald et. al. 1995), Radinja 1996, Smil 1991).

3. Results

3.1. Landscape structure

According to Ciglar (1979), the most favourable altitude level in terms of the uitability of land for agriculture is up to a height of 600 m, the second is from 600 m on. Half of the area in the Municipality of Kočevje is situated at altitudes of up to 600 m, while practically all the rest lies at the second level (Table 1).

TABLE 1: ALTITUDE LEVELS OF LAND USES BELOW AND ABOVE 600 METERS IN THE MUNICIPALITY.
PREGLEDNICA 1: RABE TAL PO VIŠINSKIH PASOVIH POD 600 M IN NAD NJIMI V OBČINI.

Altitude levels in area	Forests (ha)	%	Agricultural land (ha)	%	Abandoned agricult. land ha	%	Settlements (ha)	%	Σ (ha)	%
below 600 m	27812	45	7532	77	2725	70	1116	93	39185	51
above 600 m	33442	55	2302	23	1163	30	86	7	36993	49
Σ	61254	100	9834	100	3888	100	1202	100	76178	100

Less steep slopes dominate in the region, and nearly three quarters of the area is situated on slopes below 25%. Geomorphically, the Kočevje region is a typical karst area in which the faults run in a characteristic Dinaric northwest to southeast direction. Therefore, the main plateaus and valleys also run in this direction (Knez et. al. 1992).

TABLE 2: LAND USE IN MUNICIPALITY ACCORDING TO SLOPES (IN %).
PREGLEDNICA 2: RABE TAL V OBČINI PO NAGIBIH (V %).

Slopes	Forests		Agricultural land		Abandoned agricultural land		Settlements		Σ	
	(ha)	%	(ha)	%	(ha)	%	(ha)	%	(ha)	%
0–4%	7313	12	3976	40	1052	27	798	66	13139	17
5–14%	18547	30	3369	34	1656	43	308	26	23880	31
15–24%	16733	27	1701	17	918	24	75	6	19427	26
25–34%	9151	15	499	5	214	5	17	2	9881	13
35–44%	4585	8	167	2	37	1	2		4791	6
45–54%	2384	4	78	1	11		1		2474	3
55–64%	1354	2	30	1	0		1		1385	2
65–74%	610	1	12		0		0		622	1
75–84%	302	1	1		0		0		303	1
85–94%	130		1		0		0		131	
95–104%	73		0		0		0		73	
above 104%	72		0		0		0		72	
Σ	61254	100	9834	100	3888	100	1202	100	76178	100

The bedrock consists mainly of limestone and dolomite, and to some extent of Tertiary and Quaternary rock (*Osnovna geološka karta* 1974). The soils are mainly brown soils, rendzinas, and occasionally acid brown soils that are highly suitable for the development of natural green forest cover (Puncer 1980). With precipitation from 1330 mm to over 1900 mm per year (an average of almost 1600 mm), the region ranks among the areas in Slovenia that are wet above average. Owing to the karst bedrock, there are hardly any surface waters, except at the southern edge. Temperatures are just below the Slovene average (Hočevar, Kajfež-Bogataj 1983).

Of the natural energy sources, solar radiation is the most important for the region. The Kočevje region receives on average 1100 kWh/m^2 of solar radiation annually. Owing to the relatively clear-cut distribution of agricultural land in low-lying areas and forest in other areas, the average differences among various forms of land use are minimal. Water energy and wind energy are of minor importance for the biotic processes in the area.

The Kočevje region is one of the most typical examples of a forest landscape matrix in Slovenia. It is composed primarily of different forms of Dinaric fir-European beech forests, followed by various European beech-oak communities, highly productive fir forests on acid soils, as well as sites of valuable broad-leaved species and of pine forests. At present, almost a quarter of the forests in the region have a quite changed tree composition. Most are forests with an artificial dominance of Norway spruce and some have an artificial dominance of European beech. Many have a low site productivity. They are developing from abandoned farmland that has reverted first to scrub and then to woodland. They require high investments. In intensively managed forests, the biomass amounts to 130–350 tons of dry matter per hectare, and in less productive areas and scrublands, only to about 110 tons. Farmland was analyzed in detail only on three state-owned farms. It was divided into cultivated fields, meadows, and pastures, although nowadays the internal borders between meadows and fields are often not permanent. Their proportion is more influenced by socioeconomic than natural conditions. In pastures, the biomass amounts to over 16 tons, in meadows to over 19 tons, and in fields to over 21 tons of dry matter per hectare.

The Kočevje region as a whole has never been hospitable for human habitation. It was settled in the fourteenth century, owing to special conditions in the period of feudalism (Kundegraber 1995). Demanding conditions for farming hardly made a subsistence existence barely possible for the increasing population. New possibilities for survival were therefore sought in the continuous clearing of forests and in trade. Due to emigration, jobs were created outside traditional fields. World War II practically destroyed the exisiting cultural landscape. After the war, agriculture was developed only in the most suitable and accessible areas. Industry is now concentrated in the vicinity of Kočevje, while forestry is to be found in the rest of the region. The effects of intensive farming are particularly evident on state-owned holdings due to the monoculture management of large areas. The consequences of earlier forestry management are obvious in the proportion of preserved and changed forests, particularly the changes in tree composition and the developmental stages of forests. The effects of socioeconomic conditions are reflected in the development of large holdings in the valley encouraged by the post-war authorities, while the remaining area was more or less neglected. Thus, this extensive area has never quite recovered from war conditions. As a result, there is a very high proportion of forest land in this region.

3.2. Functioning of the landscape

3.2.1. Natural incoming energy

On average, the Kočevje region receives almost 1100 kWh/m^2 of solar radiation annually. Settled areas receive the most energy of solar radiation per unit of area, forests receive the least energy, and farmland and abandoned farmland reverting to scrub and woodland receive intermediate values. There is not much difference between forests and farmland, only by about 26 kWh/m^2. The differences are more essential for individual forms of land use in extreme positions. Thus, the forest area begins in the energy class 475 kWh/m^2, farmland begins with 675 kWh/m^2, settled areas begin with 775 kWh/m^2, and abandoned farmland reverting to scrub and woodland begins with 875 kWh/m^2. This is obvious since the forests are growing on slopes and aspects that are not suitable for agriculture (Table 3).

TABLE 3: INCOMING ENERGY OF QUASIGLOBAL SOLAR RADIATION FOR DIFFERENT LAND USES IN THE MUNICIPALITY (IN KWH/M^2).
PREGLEDNICA 3: PRISPELE CELOLETNE ENERGIJE KVAZIGLOBALNEGA OBSEVANJA PO ZEMLJIŠKIH KATEGORIJAH V OBČINI (V KWH/M^2)

	Forests		Agricultural land		Abandoned agricultural land		Settlements		Σ	
kWh/m^2	area (ha)	energy (kWh)	area (ha)	energy (kWh)	area (ha)	energy (kWh)	area (ha)	energy (kWh)	area (ha)	energy (kWh)
475	4	1896	0	0	0	0	0	0	4	1896
525	10	5250	0	0	0	0	0	0	10	5250
575	14	8050	0	0	0	0	0	0	14	8050
625	25	15625	0	0	0	0	0	0	25	15625
675	44	29700	1	675	0	0	0	0	45	30375
725	101	73225	1	725	0	0	0	0	102	74052
775	241	186775	6	4650	0	0	1	775	248	192200
825	481	396825	9	7425	0	0	2	1650	492	405900
875	1128	987000	14	12250	9	7875	1	875	1152	1008000
925	2243	2074775	58	53650	23	21275	2	1850	2326	2151550
975	4186	4081350	192	187200	96	93600	4	3900	4478	4366050
1025	7105	7282625	530	543250	283	290075	34	34850	7952	8150800
1075	11065	11894875	1838	1975850	883	948225	178	191350	13964	15011300
1125	17234	19388250	4994	5618250	1743	1960875	830	933750	24801	27901125
1175	13028	15307900	1770	2079750	742	871850	124	145700	15664	18405200
1225	4345	5322625	421	515725	109	133525	26	31850	4901	6003725
Σ	61254	67056746	9834	10999400	3888	4327300	1202	1346550	76178	83731098
kWh/m^2		1094.73		1118.51		1112.99		1120.26		1099.15

3.2.2. Artificially introduced energy

Artificial energy can be divided into directly-introduced energy inputs and energy inputs that are not directly introduced but are used at a higher energy level. The former include human labour and machine work, costs of spare parts, depreciation of machinery, and material inputs with integrated energy such as artificial and natural fertilizers, pesticides, protective repellent substances, and seeds and plants. The latter consist of purchases, electricity, and the construction and maintenance of communications intended for the functioning of state-owned enterprises and forest enterprises. They do not represent direct inputs into an individual ecosystem.

Among the farmland categories, pastures receive the least amount of introduced energy, that is, about 0.45 kWh/m^2, meadows 0.67 kWh/m^2, and fields over 1.26 kWh/m^2. The internal structure of these inputs is interesting. All the work done in the pastures, including depreciation of machinery and spare parts, accounts for over one fifth of all artificial energy inputs, and material inputs account for as much as four fifths. All the work done in the meadows, including depreciation of machinery and spare parts, accounts for over a quarter of all artificial energy inputs and material inputs account for less than three quarters. All the work done in the fields, including depreciation of machinery and spare parts, accounts for almost 40% of all artificial energy inputs, and material inputs account for over 60% (Pirnat 1998a). See Tables 4 and 5.

TABLE 4: ARTIFICIAL DIRECT ENERGY INPUTS IN AGRICULTURE IN THE SAMPLE AREA.
PREGLEDNICA 4: UMETNO VNESENI DIREKTNI ENERGIJSKI VHODI V KMETIJSTVU V VZORČNEM OBMOČJU.

Energy input	Fields kWh/ha	Fields %	Meadows kWh/ha	Meadows %	Pastures kWh/ha	Pastures %
Work, depreciation, spare parts	4823.73	38.2	1831.80	27.4	896.72	21.6
Material inputs	7817.91	61.8	4851.98	72.6	3610.41	78.4
Σ (kWh/ha)	12641.64	100.0	6683.78	100.0	4507.13	100.0
Σ (kWh/m^2)	1.26		0.67		0.45	

In forested areas, artificial energy inputs amounted to 0.24 kWh/m^2 for the whole forest area in 1993. The machine work and human labour needed for felling and skidding, silvicultural and protective measures, and depreciation of machinery and spare parts in managed forests account for less than 28% of all energy inputs; the costs of road construction and maintenance of forest communications for 71%; and materials inputs for just over 1% (Pirnat 1998a, b).

TABLE 5: STRUCTURE OF ARTIFICIAL ENERGY INPUTS IN FORESTS.
PREGLEDNICA 5: STRUKTURA UMETNO VNESENIH ENERGIJSKIH VNOSOV V GOZDOVE.

Energy inputs	Silvicultural and protection measures kWh/ha	Felling and skidding kWh/ha	Σ kWh/ha	Σ %
Work, depreciation, spare parts	2.77	659.18	661.95	27.6
Material inputs	33.19	–	33.19	1.4
Σ (kWh/ha)	35.96	659.18	695.14	
Road construction and maintenance	1703.98	71.0		
Σ (kWh/ha)	2399.12	100.0		
Σ (kWh/m^2)	0.24			

If just the costs of felling and skidding and silvicultural and protective measures are compared, that is, the direct inputs in individual subcompartments, without taking into account the construction of communications, we can observe interesting differences in energy inputs between management classes. The lowest costs were required in less intensively managed forests, in managed categories of thermophilic European beech forests, and in forests with low productivity, while the highest costs were required in intensively managed forests. In intensively managed forests, the energy inputs for felling and skidding are generally two to three times higher than in forests with low productivity (Pirnat 1998a).

Energy inputs of machine work for silvicultural measures are particularly high in stands with an artificial dominance of Norway spruce, while energy inputs in the form of material inputs such as planting are especially high in stands with low productivity. Energy inputs for protective measures are about three times higher than for silvicultural measures. Their internal structure also differs, since they require practically no machine work. All the costs are due to material inputs such as repellents, pheromones, and fences. Measures requiring the most energy were carried out in forests whose natural composition was changed, that is, in forests with a dominance of Norway spruce. The ratio between natural and artificial energy inputs remains most unequally balanced in favour of incoming solar energy. Artificial inputs into cultivated fields attain about 1‰ of solar radiation energy, and inputs into other areas are even much lower.

TABLE 6: MACHINE WORK, SPARE PARTS, AND DEPRECIATION IN FOREST PRODUCTION AS ENERGY INPUTS IN THE WHOLE AREA FOR DIFFERENT MANAGEMENT CLASSES OF FORESTS.
PREGLEDNICA 6: STROJNO DELO, REZERVNI DELI IN AMORTIZACIJA PRI PRIDOBIVANJU LESA KOT ENERGIJSKI VNOS NA CELOTNI POVRŠINI PO GOSPODARSKIH RAZREDIH GOZDOV.

	Forest production as energy inputs (in kWh/ha)								
Management class	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550
Fir-beech, dominance of beech									●
Oak-beech stands									●
Beech stands									●
Fir-beech, dominance of spruce									●
Fir-beech, group-graded management								●	
Fir-beech low-lying stands								●	
Low-lying, dominance of spruce						●			
Fir-beech, selection management					●				
Beech stands on silicate parent rock			●						
Preferential areas for game			●						
Protective forests			●						
Low-yield stands	●								
thermophilic beech stands	●								

TABLE 7: MACHINE WORK, SPARE PARTS AND DEPRECIATION, MANUAL WORK, AND MATERIAL INPUTS IN THE FORM OF SILVICULTURAL MEASURES AS ENERGY INPUTS IN THE WHOLE AREA FOR DIFFERENT MANAGEMENT CLASSES OF FORESTS.
PREGLEDNICA 7: STROJNO DELO Z AMORTIZACIJO IN REZERVNIMI DELI, ROČNO DELO IN SNOVNI VNOSI PRI GOJITVENIH DELIH KOT ENERGIJSKI VHODI GLEDE NA CELOTNO POVRŠINO PO GOSPODARSKIH RAZREDIH GOZDOV.

	Silvicultural measures as energy inputs (in kWh/ha)								
Management class	0–1	1–2	2–3	3–5	5–10	10–15	15–20	20–25	25–30
Low-yield stands									●
Fir-beech, dominance of beech						●			
Oak-beech stands						●			
Fir-beech, dominance of spruce					●				
Fir-beech low-lying stands					●				
Low-lying, dominance of spruce					●				
Fir-beech, group-graded management				●					
Beech stands				●					
Fir-beech, selection management				●					
Beech stands on silicate parent rock		●							
Preferential areas for game	●								
thermophilic beech stands	●								
Protective forests	●								

In the cultural landscape, we distinguish between energy outputs that result from the functioning of any natural system such as respiratory outputs and energy outputs that are due to socioeconomic human activities. In natural outputs, energy leaves the system in the form of heat at the end of a chain. Socioeconomic outputs are all the material outputs of a certain system designed by humans to satisfy their needs. These outputs are today all products for the market and for local consumption from farmland and forest areas. In 1993, they (sold produce and concentrate) amounted to 1.05 kWh/m^2. In forestry, these outputs can be measured by the annual allowable cut. In 1993, they amounted to 0.96 kWh/m^2 for all the forest area.

TABLE 8: MATERIAL LABOUR AND MATERIAL INPUTS IN THE FORM OF PROTECTIVE MEASURES AS ENERGY INPUTS IN THE WHOLE AREA FOR DIFFERENT MANAGEMENT CLASSES OF FORESTS.
PREGLEDNICA 8: ROČNO DELO IN SNOVNI VNOSI PRI VARSTVENIH DELIH KOT ENERGIJSKI VHOD GLEDE NA CELOTNO VZORČNO OBMOČJE PO GOSPODARSKIH RAZREDIH GOZDOV.

	Protection measures as energy inputs (in kWh/ha)										
Management class	0–2	2–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50
Low-lying, dominance of spruce											●
Fir-beech low-lying stands											●
Fir-beech, dominance of spruce									●		
Low-yield stands					●						
Fir-beech, selection management					●						
Preferential areas for game				●							
Beech stands				●							
Fir-beech, group-graded management			●								
Fir-beech, dominance of beech			●								
Oak-beech stands		●									
thermophilic beech stands		●									
Beech stands on silicate parent rock		●									
Protective forests	●										

Resistance is characteristic of all processes of energy conversion. There are three forms of resistance: natural, socioeconomic, and human. A form of the highest resistance can be seen in the passage of solar radiation through the atmosphere. Another kind of resistance is the result of the spectral value of solar radiation energy. Temperature can also be regarded as a form of resistance that interferes with the growth of certain crops. Another kind of resistance is the respiration of plants (20–55% of gross primary production) and approximately 10% of the energy yield when energy in animals changes to a further feeding phase. Forms of resistance are also found in different yields of farm and forest machines, as well as in their mechanical condition.

Socioeconomic and human resistance is difficult to evaluate since the factors to be considered can include the organization of various services, the number, structure, competence and motivation of personnel, ownership, market conditions, and the general economic situation in the country.

The ratio between primary production on one hand and artificial and maintained biomass as a criterion of energy efficiency on the other shows that energy efficiency is the highest for forests, while farm crops have an essentially lower yield. The ratio between incoming natural and introduced artificial energy is similarly significant.

TABLE 9: RATIO BETWEEN NATURAL INCOMING ENERGY (P1) AND SUPPORTED BIOMASS (B) FOR DIFFERENT ECOSYSTEMS.
PREGLEDNICA 9: RAZMERJA MED NARAVNO PRISPELO ENERGIJO (P1) IN VZDRŽEVANO BIOMASO (B) ZA RAZLIČNE EKOSISTEME.

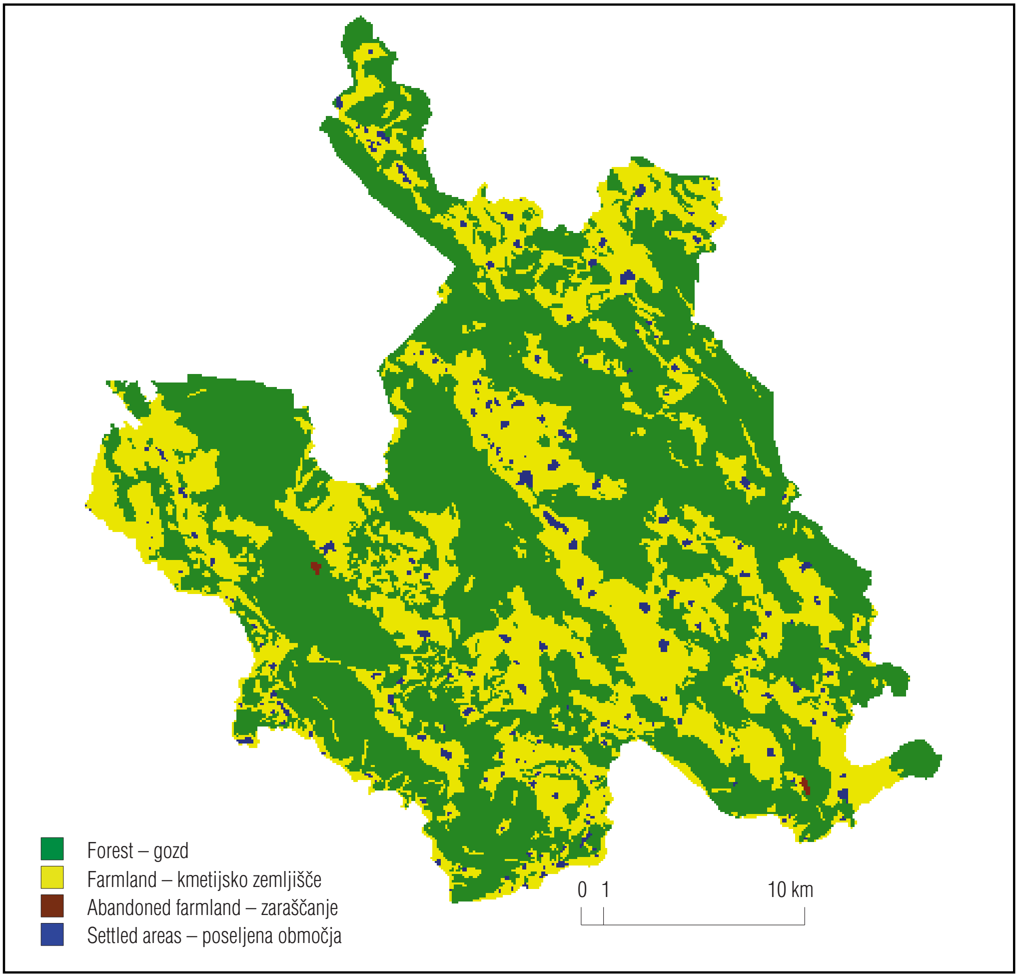
Ecosystem	P1 (kWh/m^2)	B (kg/m^2)	P/B (kWh/kg)
Field	1120.75	2.15	521
Meadow	1120.75	1.96	572
Pasture	1120.75	1.65	679
Managed forest	1094.84	15–35	73–31

Forests retain their biomass for decades, the intensity of thinning depends on the structure and condition of the forests, thinning is carried out in ten-year cycles, and production periods are between 110 and 160 years. Agricultural ecosystems have all the characteristics of highly fluctuating one-year cycles during which most of the biomass is removed. Forests contain much more oxygen than agricultural systems. They therefore act as a basic source of this element in the environment. In addition, material inputs in forests are low compared with agricultural systems. Forests have a better self-regulating system, since they can exist without any artificial energy inputs. On the other hand, agricultural system cannot exist without them. As forests can grow practically anywhere, they are much more suited for the natural conditions of the Kočevje region, whereas farmland is being increasingly abandoned. In addition, forests have an important stabilizing effect on the environment because they play a major protective role in the karst area.

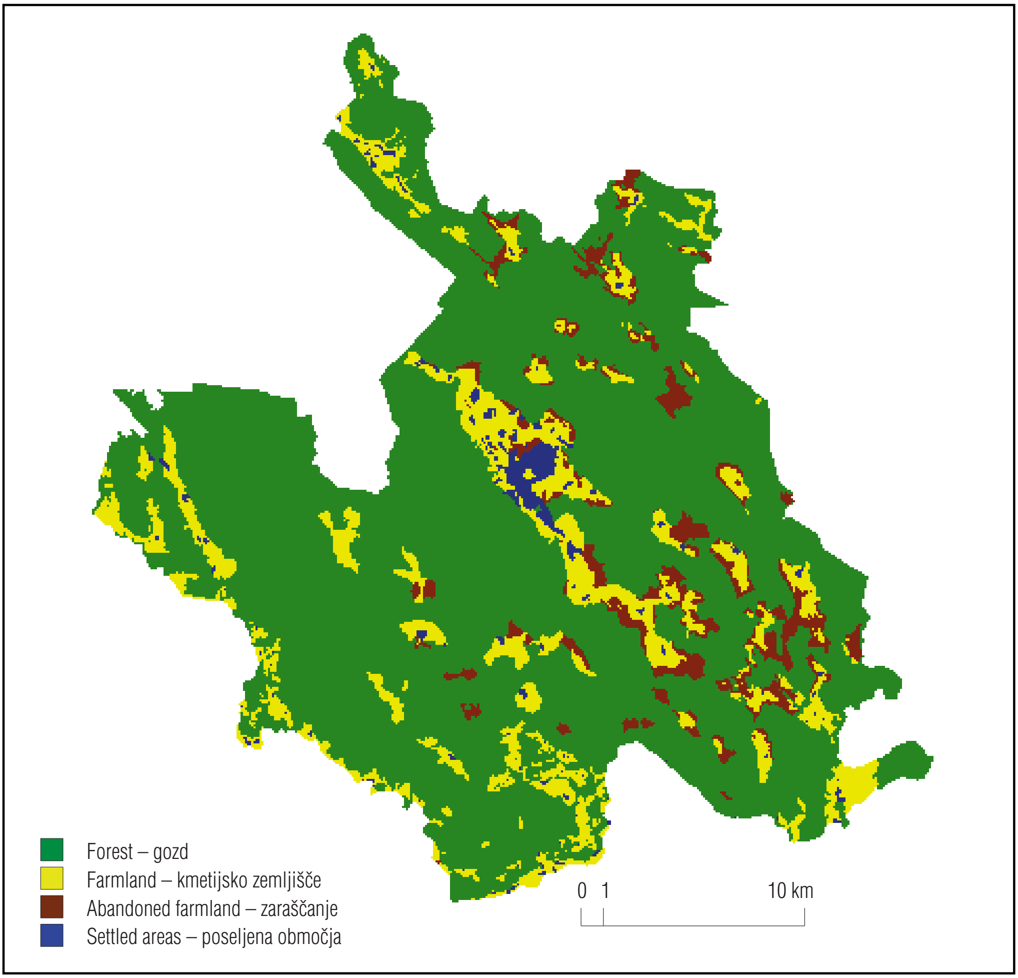
TABLE 10: RATIO BETWEEN NATURAL INCOMING (P1) AND ARTIFICIALLY INTRODUCED ENERGY (P2) FOR DIFFERENT ECOSYSTEMS.
PREGLEDNICA 10: RAZMERJA MED NARAVNO PRISPELO (P1) IN UMETNO VNESENO ENERGIJO (P2) ZA RAZLIČNE EKOSITEME.

Ecosystem	P1 (kWh/m^2)	P2 (kWh/m^2)	P1 + P2 (kWh/m^2)	P1 / P2
Field	1120.75	1.26	1122.01	889
Meadow	1120.75	0.67	1121.42	1673
Pasture	1120.75	0.45	1121.20	2490
Managed forest	1094.84	0.24	1094.24	4562

3.2.3. Changes in the landscape of the Kočevje region



Map 1: Land Use in the Municipality of Kočevje, 1763–1778 (Rajšp 1996).
Karta 1: Rabe tal v občini Kočevje v letih 1763–1778 (Rajšp 1996).



Map 2: Social Plan for Land Use in the Municipality of Kočevje, 1981–1985.
Karta 2: Rabe tal v občini Kočevje po družbenem planu 1981–1985.

Changes in the landscape of this region have been reported over the last two hundred years. Comparisons show a decrease in the forest area at the end of the eighteenth and in the beginning of the nineteenth century. This trend is then followed by a continuous increase in the forest area, mainly on account of areas that are suitable for agriculture, particularly pastures. The changes result from socioeconomic conditions. At the same time we can also observe an increase in artificial energy inputs into the area, but they are confined only to land most suitable for farming owing to socioeconomic and political conditions. Inputs into the fields have been increased by over a hundred times, into meadows by about seventy times, and into pastures and forests by some ten times.

4. Energy flows in forests and agricultural landscapes – conclusions

Intensively managed forests where direct artificial energy flows amount to between 0.250 and 0.255 kWh/m^2 annually account for 39% of the sample area, or 47% of the area of the former Municipality of Kočevje.

These are Dinaric fir-European beech forests and European beech-oak forests in the Dinaric karst area of the Velika gora, Mala gora, Rog, and Goteniški Snežnik massifs.

Low-lying forests with a dominance of Norway spruce, where direct artificial energy flows amount to between 0.24 and 0.25 kWh/m^2 annually, account for 14% of the sample area and 8% of the former Municipality of Kočevje. It is typical that they cover areas closest to farmland and settlements along the valleys, which is also the reason they were changed to such a stand form due to management measures taken in the past. Selectively managed forests, where direct artificial energy flows amount to between 0.23 and 0.24 kWh/m^2 annually, account for 4% of the sample area and 6% of the former Municipality of Kočevje. They depend on natural conditions, that is, the tree species Norway spruce, fir, and European beech are to be found as smaller patches among other forms of fir-European beech forests.

Less intensively managed forests, where direct artificial energy flows amount to between 0.21 and 0.23 kW/m^2, account for 18% of the sample area and 19% of the former Municipality of Kočevje. These forests are situated in steep protective positions or have been left as game reserves or have developed on abandoned farmland.

Regenerated areas on abandoned farmland, areas covered with shrubs, and forest areas that are not managed where reserves are located account for 9% of the sample area and for 5% of the Kočevje municipality. Dependent on solar energy only, these areas operate without artificial energy inputs.

Farmland accounts for 14% of the sample area and for 13% of the whole municipality. These are areas where direct artificial energy flows amount to between 0.45 and 1.26 kWh/m^2 annually.

Settled areas account for 2% of the sample area and of the area of the municipality. The artificial energy flows for these areas were not evaluated. This data can be obtained only from literature. According to Odum (1989), artificial energy flows in urban-industrial systems range from over 100 kWh/m^2 to 3500 kWh/m^2 annually, over 2000 kWh/m^2 on average.

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6. Summary in Slovene – Povzetek

Naravni in umetni energijski tokovi v gozdnih in kmetijskih ekosistemih Kočevske

Janez Pirnat

1. Uvod

Kočevsko leži v južnem delu Slovenije. Geološko jo označujeta apnenec in dolomit, glavna vegetacijska značilnost so obsežne površine jelovih in bukovih gozdov, socialna posebnost pa so majhna razpršena naselja okrog mesta Kočevje. Gozdarstvo in kmetijstvo sta glavni rabi tal v prostoru.

Človek je z ročnim in živalskim delom ter z orodji že od nekdaj zmogel preoblikovati podobo Zemlje v kulturno krajino, ki mu omogoča preživetje, vedno boljšo naselitveno kulturo in duhovni razvoj. Za obdobje pred industrijsko revolucijo je značilna razmeroma počasna rast porabe energije. Z industrijsko revolucijo začne človek postopno izkoriščati uskladiščeno fosilno energijo. Uporaba fosilne energije je omogočila človeku skokovit razvoj, hkrati pa je z njo ustvaril celo vrsto umetnih sistemov, kot so npr. industrijski obrati, mesta, povezovalna infrastruktura, ki so danes osnova moderne družbe.

Odum (1989) ločuje a) naravna, b) udomačena in c) umetna okolja, ki jih pozna naša doba, vsako izmed njih pa označujejo tudi različna notranja razmerja med prispelimi naravnimi in vnesenimi umetnimi energijskimi tokovi.

a) Naravna okolja poganja sončna energija in njene posredne oblike, kot so vetrovi, vodni tokovi in deževja pa tudi sila gravitacije. V to kategorijo sodijo naravni, negospodarski gozdovi.
b) Udomačena okolja še vedno poganja prispela sončna energija, del energije pa vnaša v sistem človek preko ročnega, živalskega in strojnega dela ter vnesenih snovi, kot so škropiva, semena, gnojila. Sem sodijo gospodarski gozdovi in kmetijska zemljišča. Ta vrsta okolja obsega največji del našega planeta.
c) Umetna okolja so danes mesta in industrijski centri s povezovalno infrastrukturo, ki jih posredno ali neposredno poganja fosilna energija. Ta okolja se danes najhitreje širijo, prav tako pa so največji potrošnik umetnih energijskih vnosov (Odum 1989).

Prvi dve okolji označuje E. Odum kot sistema, ki podpirata življenje, saj v njih pridobivamo hrano, prav tako pa v njih izrabljajo rastline preko fotosinteze sončno energijo in ustvarjajo fitomaso, uravnavajo vodne in zračne tokove ter vplivajo na mineralne kroge.

Osnovne krajinsko ekološke pojme in podatke o Kočevski povzemamo iz uveljavljene domače in tuje literature (Anko 1986, Ciglar 1979, Forman 1995, Naveh/Lieberman 1994, Naveh 1994, Puncer 1980, Zonneveld 1995.)

Naša raziskava o energijskih tokovih je potekala na Kočevskem. Kočevska krajina je snovno in energijsko odprt sistem, v katerem odločilno zaznamuje tokove in meje vplivov snovi in energije človek; ta hkrati prav s tem odločilno vpliva na sposobnost določene samoregulacije ekosistemov, ki jo sestavljajo. Meje kulturne krajine danes najmočneje nakazujejo upravno administrative meje, zato so tudi najbolj smiseln okvir raziskav v kulturni krajini. Zaradi tega smo tudi obravnavali Kočevsko s površino, ki jo je leta 1993 zavzemala takratna občina Kočevje.

Na kakovostne spremembe v krajini lahko opozorimo s študijem tokov snovi in energije. Krajinskoekološko členitev krajine smo povzeli po Ankovi (1986) shemi zgradbe in delovanja krajine, upoštevali pa smo tudi spremembe v krajini, ki se kažejo kot spremembe kateregakoli izmed dejavnikov zgradbe in delovanja krajine.

Ožje opredeljeni raziskovalni cilj so bili:

- opredeliti strukturne značilnosti obravnavane krajine,
- opredeliti vrsto in velikostni razred naravnih in umetnih energijskih tokov na nivoju krajine, v kateri prevladuje gozdna matica z zaplatami kmetijske rabe,
- opredeliti, v katerih ekosistemih v krajini nastopajo posamezne vrste energijskih vhodov, kje prevladujejo naravni energijski tokovi, kje umetni energijski vnosi in kje sta zastopana oba energijska vnosa oziroma kakšno je razmerje med njima,
- opredeliti povezavo med zunanjimi znaki spremenjenosti posameznih ekosistemov in različnimi deleži umetno vnesene energije, ki so zanje značilni,

Z prispevkom želimo preveriti naslednje hipoteze:

- pomembni dejavniki pri razumevanju krajine so njena zgradba, delovanje in spremembe v njej. Za vse tri sklope je pomembno razmerje med naravnimi in družbenimi dejavniki, pri čemer so slednji najpomembnejši dejavnik, ki vpliva na spremembe kulturne krajine,
- nekdanja Kočevska je nastala v pretežni meri z vlaganjem umetne energije v obliki človeškega dela v ta prostor, sedanja nastaja zaradi sprememb in vlaganja novih oblik umetne energije v zadnjega pol stoletja. Njeno današnjo krajinsko strukturo prikazuje trenutno razmerje med naravnimi danostmi in človekovo rabo prostora. Njena prihodnost je odvisna od človekovih vlaganj v izbrane rabe prostora,
- poznavanje energijskih tokov med ekosistemi, ki povezujejo krajino v funkcionalno celoto, je odločilen dejavnik pri notranji členitvi prostora na posamezne tipe ekosistemov, kar bodo v našem primeru skupine ekosistemov s podobnimi energijskimi tokovi. Homogenost obravnavamo z vidika temeljnih

ekoloških zakonitosti (zgradba, delovanje, razmerje med naravno prispelo in umetno vneseno energijo, ustvarjeno biomaso v kmetijskih ekosistemih oziroma ustvarjeno in vzdrževano biomaso v gozdu),
- gospodarski gozdovi se razlikujejo med seboj v različnih razmerjih med naravno prispelo in umetno vneseno energijo,
- gospodarski gozdovi in kmetijska zemljišča se razlikujejo tudi po nihanjih energijskih vnosov oziroma mestu (pri gozdovih tudi v razvojni fazi) vlaganj.

2. Metode dela

Gozdove in kmetijska zemljišča smo primerjali glede na:

- količino organske snovi,
- razmerje med naravno prispelo in umetno vneseno energijo,
- strukturo umetno vnesene energije (delo ljudi in strojev, vnosi energije, vezani v snovi, npr. gnojila, semena, zaščitna sredstva).

Pri delu smo izhajali iz naslednjih dveh izhodišč:

Kočevska je obsežna krajinska enota, zato je z razpoložljivimi sredstvi in časom ne moremo obravnavati v celoti z enako natančnostjo. Splošne danosti prostora in podatke o naravno prispeli energiji smo tako obravnavali za celotno občino Kočevje, to je za 762 km^2. Umetne energijske vnose pa smo zaradi obsežnosti dela podrobneje obravnavali v določenih izbranih predelih, s tem da smo vgradili v raziskavo iztočnice tudi za ostali prostor. Vzorčno območje tako zajema 353 km^2 ali 46 % nekdanje občine Kočevje. Za gozdarski del raziskave so obravnavani gozdni predel predstavljali posamezni odseki v gospodarskih enotah. Gre za tipične gospodarske enote današnje Kočevske. Za kmetijski del raziskave smo se opirali na vsa tri družbena posestva, ki ležijo na istem področju, s katerimi upravlja Mercator Kmetijsko Gospodarstvo (MKG) Kočevje. Te smo obravnavali kot vzorčne kmetijske površine. Podatke o vseh energijskih vlaganjih smo primerjali za vzorčno leto 1993.

V prvem delu raziskave smo se usmerili v energijska vrednotenja naravno prispelih energijskih tokov. Sem sodi v prvi vrsti sončna energija. Za naše potrebe smo izračunali energijo kvaziglobalnega sončnega obsevanja na Geografskem inštitutu ZRC SAZU s pomočjo računalniškega programa »Sonce« (Gabrovec 1996). Vsi izračuni so bili izdelani po enournih intervalih za postajo Novi Lazi pri Kočevju (Hočevar 1980). Podatke o nagibu in legi smo dobili iz slovenskega DMR 100. Program upošteva formuli za direktno in difuzno obsevanje, kot jih navaja Hočevar s sodelavci (1980):

Druge podatke o prostoru je bilo potrebno predhodno še spremeniti v vektorsko obliko; obdelali smo jih s programom ROOTS 1.0 (Corson-Rikert 1992). Sem sodijo karte Družbenega plana rabe tal območja Kočevske za obdobje 1981–1985 v merilu 1 : 50.000, geološka, fitocenološka in pedološka karta Kočevske v merilu 1 : 200.000, karta padavin na Kočevskem ter karte jožefinskih merjenj Kočevske v merilu 1 : 28.800 (Rajšp 1996). Vse vsebinske primerjave in prekrivanja smo obdelali s pomočjo geografskega informacijskega sistema IDRISI 4.1 (Eastman 1993), računske obdelave in preglednice s pomočjo programa EXCEL 5.0 v okolju Microsoftovih Oken, izrise kart pa s programom COREL DRAW 5.0.

Podatke o umetnih energetskih vhodih in podatke o proizvodnji za leto 1993 smo dobili za kmetijski prostor pri MKG Kočevje, za gozdove pa na GG Kočevje in na Zavodu za gozdove Republike Slovenije. Zgodovinske podatke o družbenogospodarskem razvoju prostora ter osnovne podatke o naravnih značilnostih prostora smo povzeli po literaturi.

Pri podatkih o gozdarski proizvodnji smo izhajali iz denarnih nadomestil za delo v gozdni proizvodnji in pri gojitvenih ter varstvenih delih v letu 1993. Iz teh podatkov je razviden delež nadomestil za gorivo in mazivo na eni strani ter nadomestil za rezervne dele in amortizacijo pri delu s stroji. Pri gojitvenih delih smo upoštevali dela, kjer se pojavljajo ročne in strojne ure. Prav tako smo upoštevali tudi ure ročnega dela pri varstvenih delih. Ker se sečnja in gojenje ne ponavljata vsako leto na isti površini, je bilo potrebno opravljena dela na dejanski površini preračunati na celotno površino gozdov, torej tudi na tiste površine, kjer v omenjenem letu niso delali. Le tako namreč lahko primerjamo gozdarska vlaganja s kmetijskimi, hkrati pa tudi tako izravnamo posebnosti gozdarskih vlaganj.

Na kmetijskih površinah je slika drugačna, tu so se podatki nanašali na izrabo vseh površin v letu 1993, seveda z razlikami med posameznimi, ki so odvisne tudi od posameznih kultur. Tudi tu smo uporabljali podatke o vnesenem gorivu in mazivu na eni strani ter nadomestila za rezervne dele in amortizacijo pri delu s stroji. Prav tako smo upoštevali ročne in strojne ure.

Za vsako rabo tal smo podatke o številu ur dela posameznih strojev na določeni površini pomnožili z njihovo močjo in tako dobili vrednosti v kWh. Stroške v tolarjih za gorivo in mazivo smo spremenili v kWh tako, da smo ceno delili s tehtano ceno nafte za leto 1993 (52,73 SIT na liter). Energijska vrednost nafte je med 42 in 44 MJ/kg, povprečno 43 MJ na kg, gostota pa 0,8 kg na dm^3 (Smil 1991, Anko 1985), torej je energijska vrednost enega litra nafte okrog 9,55 kWh. Enako metodo smo uporabili tudi za oceno nekaterih drugih stroškov (rezervni deli, amortizacija, gozdne gradnje), za snovne vnose pa smo uporabili energijske vrednosti iz literature (Leskošek 1993, McDonald et. al. 1995, Radinja 1996, Smil 1991).

3. Rezultati

3.1. Zgradba krajine

Po Ciglarju (1979) je 600 m nadmorske višine tista meja, ki kaže do kod sega višinski pas, primeren za kmetijstvo. V občini Kočevje leži nekaj čez polovico vse površine v nadmorskih višinah do 600 m in praktično vsa druga površina v drugem višinskem razredu. Podrobnosti so v preglednici 1.

Na Kočevskem prevladujejo manj strmi nagibi, saj skoraj tri četrtine ozemlja leži v nagibih do 25 %. Geomorfološko je Kočevska tipičen kraški svet s prelomnicami v značilni dinarski smeri NW–SE. Zaradi tega so v tej smeri obrnjene tudi glavne planote in doline (Knez et. al. 1992).

Geološko podlago Kočevske sestavljata največ apnenec in dolomit, manjše dele zavzemajo terciarne in kvartarne kamenine (Osnovna geološka karta 1974). Na njih so se razvila v pretežni meri rjava pokarbonatna tla, rendzine in mestoma tudi kisla rjava tla, zelo primerna za naravno zeleno gozdno odejo (Puncer 1980). Kočevska prejema od 1300 do preko 1900 mm padavin na leto, v povprečju skoraj 1600 mm in spada torej med nadpovprečno vlažne predele pri nas (Klimatografija Slovenije 1995). Kočevska zaradi kraških kamenin, razen na južnem obrobju, skoraj ne pozna površinskih voda. Temperaturno sodi Kočevska rahlo pod slovensko povprečje (Hočevar, Kajfež-Bogataj 1983).

Izmed naravnih virov energije je za Kočevsko najpomembnejša energija sončnega obsevanja. Kočevska prejema letno v povprečju skoraj 1100 kWh/m^2 sončnega obsevanja. Zaradi razmeroma enostavnega razporeda kmetijskih zemljišč v ravninah in gozdov povsod drugje, so povprečne razlike med različnimi rabami tal minimalne. Vodna energija in energija vetra sta za biotske procese na Kočevskem malo pomembni.

Kočevska je eden najbolj tipičnih primerov gozdne krajinske matice v Sloveniji. Tu prevladujejo različne oblike dinarskih jelovo-bukovih gozdov, sledijo jim različne bukove in hrastove združbe, visoko produktivna jelovja na kislih tleh, najdemo pa tudi rastišča plemenitih listavcev in borovja. Danes ima skoraj četrtina kočevskih gozdov močno spremenjeno drevesno sestavo, največkrat gre za zasmrečene gozdove, nemalokrat pa tudi za zabukovljene. Veliko je tudi malodonosnih gozdov, ki nastajajo iz opuščenih površin; te preko različnih grmiščnih stadijev prehajajo v gozdove in zahtevajo visoka vlaganja. Biomasa v intenzivnih gospodarskih gozdovih znaša od 130 do 350 ton suhe snovi na hektar, v manj donosnih površinah in grmiščih le okrog 110 ton. Kmetijska zemljišča smo podrobneje členili le v treh družbenih posestvih. Delili smo jih na njive, travnike in pašnike, čeprav dandanes notranje meje med travnikom in njivo večkrat niso trajne; na njihov delež močneje vplivajo družbenogospodarske razmere kot pa naravne danosti. Biomasa na pašniških površinah znaša dobrih 16 ton, na travniških površinah dobrih 19 ton in na njivskih površinah dobrih 21 ton suhe snovi na hektar.

Kočevska ni bila v celoti nikoli enostavna dežela za poselitev. Prostor je bil zaradi posebnih fevdalnih razmer poseljen v 14. stoletju (Kundergraber 1995). Težke razmere za kmetijstvo so komaj omogočale preživljanje naraščajočega števila prebivalstva, to pa je iskalo svoje možnosti v vedno novih krčitvah gozdov in trgovanju. Emigracija je vplivala na zaposlitev zunaj tradicionalnih panog, druga svetovna vojna pa je pomenila dobesedno uničenje tedanje kulturne krajine. Kmetijstvo se je po vojni razvijalo samo še na najboljših in najbolj dostopnih površinah, v bližini Kočevja je zgoščena tudi vsa industrija, ves ostali prostor pa dandanes oblikuje gozdarstvo. Vpliv intenzivnega kmetijstva se kaže zlasti na družbenih posestvih, kjer gospodarijo z monokulturami na velikih površinah. Vpliv preteklega gozdarjenja se kaže v deležu ohranjenih oziroma spremenjenih gozdov, predvsem v spremenjeni drevesni sestavi in razvojnih stopnjah gozdov. Družbenogospodarski vpliv se kaže v tem, kako je povojna oblast vplivala na nastanek velikih kmetijskih obratov v dolini, ostali prostor pa je obravnavala veliko bolj mačehovsko, zaradi česar se na veliki površini ni nikoli povsem opomogel od vojnih razmer, posledica pa je med drugim izjemno visoka današnja gozdnatost Kočevske.

3.2. Delovanje krajine

3.2.1. Naravno prispela energija

Kočevska prejema letno v povprečju skoraj 1100 kWh/m^2 sončnega obsevanja. Največ energije sončnega obsevanja na enoto površine prejmejo poseljena zemljišča, najmanj pa gozdovi, agrarne in zaraščajoče površine dobijo vmesne vrednosti. Vendar so razlike med gozdovi in agrarnimi površinami majhne, gre le za okrog 26 kWh/m^2 površine. Večje so razlike med skrajnimi legami za posamezne rabe tal. Gozdovi tako pokrivajo tla v razredu, ki prejmejo 475 kWh/m^2 površine, kmetijska zemljišča se začno pri površinah, ki prejmejo vsaj 675 kWh/m^2, poseljene površine se začno pri 775 kWh in zaraščajoče se površine pri 875 kWh/m^2 površine. To je razumljivo, saj poraščajo gozdovi tudi strme in osojne površine, ki so za kmetijstvo neprimerne. Podrobnosti prinaša preglednica 3.

3.2.2. Umetno vnesena energija

Umetno energijo delimo na direktno vneseno in nerazporejeno. Med direktno vneseno štejemo ročno in strojno delo, stroške rezervnih delov in amortizacije strojev ter snovne vhode kot vezano energijo, kamor štejemo umetna in naravna gnojila, škropiva, premaze oziroma zaščitna sredstva, semena in sadike. Nerazporejeni energijski vhodi so nakupi, električna energija in gradnje ter vzdrževanje prometnic, ki so vezane na delovanje družbenih obratov in gozdnega gospodarstva, ne pomenijo pa direktnih vnosov v posamezni ekosistem.

Med kmetijskimi sistemi prejmejo najmanj vnesene energije pašniki, in sicer zaokroženo 0,45 kWh/m^2 površine, travniki 0,67 kWh/m^2 in njive prejmejo dobrih 1,26 kWh/m^2 površine. Zanimiva je tudi notranja struktura teh vnosov. Pri pašnikih zavzema vse delo z amortizacijo in rezervnimi deli dobro petino vseh umetnih energijskih vnosov, kar štiri petine pa snovni vnosi. Pri travnikih zavzema vse delo z amortizacijo in rezervnimi deli dobro četrtino vseh umetnih energijskih vnosov, slabe tri četrtine pa snovni vnosi. Pri njivah zavzema vse delo z amortizacijo in rezervnimi deli skoraj 40 % vseh umetnih energijskih vnosov, snovni vnosi pa dobrih 60 % (Pirnat 1998a). Podrobnosti so v preglednicah 4,5.

Na gozdnih površinah so v letu 1993 umetni energijski vhodi znašali v povprečju 0,24 kWh/m^2 celotne površine gozdov. Strojno in ročno delo pri sečnji in spravilu, gojenju in varstvu, skupaj z amortizacijo in rezervnimi deli v gospodarskih gozdovih pomenijo le slabih 28 % vseh energijskih vlaganj, stroški gradnje in vzdrževanja gozdnih prometnic 71 % vseh energijskih vnosov, snovni vnosi pa komaj dober odstotek vseh vnosov (Pirnat 1998 a, b).

Če primerjamo samo stroške sečnje in spravila, gojenja in varstva, torej le direktne vnose v posamezne odseke, brez gradnje prometnic in prevozov lesa, so zanimive tudi razlike v energijskih vlaganjih med gospodarskimi razredi. Najmanjši stroški so bili v manj intenzivnih gospodarskih gozdovih, v gospodarskih razredih termofilnih bukovih in malodonosnih gozdov, največji pa so bili v intenzivnih gospodarskih gozdovih. Energijski vnosi pri sečnji in spravilu v intenzivno gospodarjenih proizvodnih gospodarskih gozdovih so v grobem dva-do trikrat večji kot v malodonosnih gozdovih (Pirnat 1998a).

Gojitveni energijski vnosi so pri strojnem delu še posebej veliki pri zasmrečenih sestojih, energijski vnosi v obliki snovnih vhodov – sadnje – pa pri malodonosnih sestojih. Energijski vnosi v varstvo gozdov so približno 3-krat večji od gojitvenih, različna pa je tudi njihova notranja struktura, saj tu strojnega dela praktično ni, zato zavzemajo vse stroške snovni vhodi, to so premazi, feromoni in ograje. Večina energijsko najzahtevnejših del je potekala v spremenjenih, pretežno zasmrečenih gozdovih. Primerjava naravnih in umetnih energijskih vlaganj ostaja izrazito neenaka v korist prispele sončne energije. Le umetni vnosi v njive presegajo 1 ‰ energije sončnega obsevanja, vnosi v druge površine pa so še bistveno manjši (Pirnat 1998a).

V kulturni krajini ločimo energijske izhode, ki nastopijo zaradi delovanja vsakega naravnega sistema, to so t. i. respiracijski izhodi, ter izhode, ki nastopajo zaradi družbenogospodarske dejavnosti ljudi. Pri naravnih izhodih energija na koncu katerekoli verige zapusti sistem v obliki toplote. Družbenogospodarski izhodi iz sistema pa so vsi iznosi snovi iz določenega sistema, ki jih je zaradi svojih potreb izpeljal človek. Danes lahko štejemo med družbenogospodarske izhode vse pridelke za trg in domačo porabo tako s kmetijskih in gozdnih površin. V letu 1993 so izhodi v kmetijstvu (prodana hrana in močna krmila) znašali 1,05 kWh/m^2 površine. V gozdarstvu lahko merimo tovrstne izhode z vsakoletnim posekom lesa. V letu 1993 so ti izhodi znašali 0,96 kWh/m^2 površine vseh gozdov.

Upori so značilni za vse procese, ki so v zvezi s pretvarjanjem energije. Tako ločujemo tri vrste uporov: naravne, družbenogospodarske in osebne. Enega največjih uporov lahko zasledujemo že pri prehodu sončnega obsevanja skozi atmosfero. Naslednji upor je posledica spektralne vrednosti energije sončnega obsevanja. Upor so lahko tudi temperature. Tako je lahko tudi temperatura tisti upor, ki lahko omejuje uspevanje določenih kmetijskih kultur. Nadaljnji upor je tudi respiracija rastlin (20–55 % bruto primarne proizvodnje) in približno 10 % energijski izkoristek, ko prehaja energija pri živalih v višjo prehranjevalno stopnjo. Med upore sodijo tudi različni izkoristki kmetijske in gozdarske mehanizacije. Prav tako pa tudi tehnična brezhibnost strojev.

Družbenogospodarski in osebni upori so težko merljivi, sem sodi organizacija dela posameznih služb, število, struktura ter znanje in motivacija zaposlenih, lastništvo, tržne razmere in splošno ekonomsko stanje v državi.

Razmerje med primarno proizvodnjo in ustvarjeno ter vzdrževano biomaso kot kriterij energijske učinkovitosti kaže, da je gozd najbolj učinkovito izkorišča energijo, bistveno slabši izkoristek imajo kmetijske kulture. Te ugotovitve so značilne tudi razmerje med naravno prispelo in umetno vneseno energijo.

Pri gozdovih se biomasa veže za desetletja, jakosti redčenj so odvisne od strukture in stanja gozdov, pojavljajo se v desetletnih ciklih, proizvodne dobe se gibljejo od 110 do 160 let. Kmetijski ekosistemi imajo vse značilnosti močno nihajočih enoletnih ciklov, ob katerih se odstrani pretežni del biomase. V gozdovih je tudi vezano bistveno več ogljika kot v kmetijskih sistemih, zato delujejo gozdovi kot značilen ponor tega elementa v okolju. Poleg tega so snovno vnosi v gozdove majhni v primerjavi s kmetijskimi sistemi.

Gozdovi se bolje samoregulirajo, saj za obstoj ne potrebujejo umetnih energijskih vnosov, kmetijski ekosistemi pa brez njih sploh ne morejo uspevati. Hkrati se tudi dosti bolj prilagajajo naravnim danostim Kočevske, saj zmorejo osvojiti praktično sleherno površino, medtem ko se kmetijstvo s prostora umika. Gozdovi tudi pomembno stabilizirajo okolje, saj opravljajo na kraških tleh pomembno varovalno vlogo.

3.2.3. Spremembe kočevske krajine

Spremembe kočevske krajine so dokumentirane za zadnjih dvesto let. Primerjave kažejo sicer upad gozdov ob koncu 18. in v začetku 19. stoletja, potem pa sledi nenehno naraščanje gozdnih površin predvsem na račun manj primernih kmetijskih – zlasti pašniških površin. Spremembe so posledica družbenogospodarskih okoliščin. Vzporedno zaznavamo tudi porast umetnih energijskih vnosov v prostor, vendar so zaradi družbenoekonomskih in političnih okoliščin omejeni le na najboljše kmetijske površine. Vnosi v njive so se povečali za več kot stokrat, vnosi v travnike okrog sedemdesetkrat in vnosi v pašnike in gozdove nekaj desetkrat.

4. Energijski tokovi v gozdnih in kmetijskih ekosistemih – zaključki

Intenzivni gospodarski gozdovi, v katerih direktni umetni energijski tokovi dosegajo med 0,25 in 0,255 kWh/m^2 letno, zavzemajo 39 % vzorčnega območja oziroma 47 % območja nekdanje občine Kočevje. Gre za dinarske jelovo-bukove, bukove in hrastove gozdove, ki poraščajo dinarski kraški svet masivov Velike in Male gore, Roga in Goteniškega Snežnika.

Nižinski zasmrečeni gozdovi, v katerih direktni umetni energijski tokovi dosegajo med 0,24 in 0,25 kWh/m^2 letno, zavzemajo 14 % v vzorčnem območju in 8 % v nekdanji občini Kočevje. Značilno je, da se razprostirajo najbližje kmetijskim površinam in naseljem ob dolinah, kar je tudi razlog, da so jih s preteklimi gospodarskimi ukrepi prevedli v takšno sestojno obliko.

Prebiralni gozdovi, v katerih direktni umetni energijski tokovi dosegajo med 0,23 in 0,24 kWh/m^2 letno, zavzemajo 4 % v vzorčnem območju in 6 % v nekdanji občini Kočevje. Vezani so na naravne danosti, to je smreko, jelko in bukev in se pojavljajo kot manjše zaplate med drugimi oblikami jelovo-bukovih gozdov.

Manj intenzivni gospodarski gozdovi, v katerih direktni umetni energijski tokovi dosegajo med 0,21 in 0,23 kWh/m^2 letno, zavzemajo 18 % v vzorčnem območju in 19 % v nekdanji občini Kočevje. Gre za površine, na strmih, varovalnih legah, površine, ki so namenjene divjadi in površine, ki so nastale na opuščenih kmetijskih zemljiščih.

Zaraščajoče se površine, grmišča in negospodarski gozdovi, kamor sodijo rezervati, zavzemajo 9 % površine v vzorčnem območju in 5 % v celotni občini Kočevje. Te površine delujejo brez umetnih energijskih vnosov samo preko sončne energije.

Kmetijske površine zavzemajo 14 % v vzorčnem območju in 13 % v celotni občini. Gre za površine, na katerih dosegajo direktni umetni energijski tokovi od 0,45 do 1,26 kWh/m^2 površine letno.

Poseljene površine zavzemajo 2 % tako v vzorčnem območju kot v občini. Umetnih energijskih tokov tukaj nismo ocenjevali, lahko jih povzemamo le po literaturi. Po Odumu (1989) znašajo umetni energijski tokovi v urbano-industrijskih sistemih od dobrih 100 do 3500 kWh/m^2 letno, v povprečju pa preko 2000 kWh/m^2 letno.