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ANNALES
EXPERIMENTIS SILVARUM CULTURAE PROVEHENDIS

36

SVEUČILIŠTE U ZAGREBU
ŠUMARSKI FAKULTET
UNIVERSITAS STUDIORUM ZAGRABIENSIS
FACULTAS FORESTALIS

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UDK: 630*624+628

Original scientific paper
Izvorni znanstveni članak

SD MODEL OF EVEN-AGED FOREST

SUSTAV DINAMIČKI MODEL REGULARNE ŠUME

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Received – *Prispjelo*: 1.2.1999. Accepted – *Prihvaćeno*: 15.9.1999.

A basic requirement in today's forest resources management is an ongoing production of all forest utilities with preserving the forest ecosystems stability. Considering the even-aged forest management, this requirement will be assured by achieving compositions of normal and stable forests based on normal age class order.

Faced with natural systems governed by intricate relationships in time and space, we have chosen a system-dynamic modelling as our work method, and projected a simulation model of even-aged forest management process by applying the method of age class distribution.

After simulating suitable scenarios, we focused our research on the future development of age class distribution per area and growing stock on the management unit "Lacic Glozdje", within the pedunculate oak management class.

The simulation research proved that even-aged forest management, defined by the intensity of regeneration felling (i.e. by the method of calculating the felling area of the major harvest cut) and the length of rotation, is a powerful factor affecting the future behavior (i.e. the change of age class distribution, felling areas growing stock and values) of a closed even-aged forest system.

Key words: sustainable management, even-aged forest, system dynamics, age class distribution

INTRODUCTION
UVOD

When men realized that timber was not an inexhaustible resource, he started to manage forests on the principle of sustainable forestry. Sustainability is possible to achieve by applying different methods, going through various development phases (Morecroft 1992). Sustainable revenue has been a traditional feature of forest theory and practice (Klepac 1965). The work principle in forest management is such that it enables continuing annual yields, preserving and protecting the productive capabilities of the forest (Kuik & Salomon 1994).

Sustainable management of forest resources today has a much wider concept than continuous yields of timber. The preservation of the forest resources for production of generally useful forest functions and genetic potentials is far more important.

Continuing yields of similar revenues do not necessarily mean sustainable forest management (Gane 1992a,b, Geus 1992). The right way is the search for economic progress that will not damage the welfare of future generations (Vennix 1992).

The basic principle of sustainable revenues present in the traditional theory and practice, and all legislation on forest management, should acquire a dynamic and progressive character (Meštrović 1978, 1980). A composition of stable forest of even-aged stands based on a normal age class distribution is a prerequisite.

A basic requirement faced by forest resource managers is continuing production of forest utilities with preservation of the forest ecosystem stability. Forest is a dynamic natural system governed by complex cause-consequence relations in time and space. A system of dynamic modelling may be a powerful support in deciding and planning forest management (Čavlović 1996).

Based on the created dynamic simulation model of the even-aged management process, applying the method of age class distribution and the done simulation of the suitable scenarios, the research focused on the future development of the age class distributions per area and growing stock within the pedunculate oak management class in the Management unit "Josip Kozarac". Having achieved a considerable success today, the simulation model may process all assumed future changes, that will affect the given forest assets. It is an intelligent support in forest management, appropriate for both short-term and long-term planning of physical, economic and financial elements.

MODEL PRESENTATION
PRIKAZ MODELA

The system dynamic simulation model of the even-aged forest management process presents a real forest as a closed system for achieving balance. It tries to encompass and describe all effective factors within and out of the system (biological disturbances, management practices), that may affect the time of achieving the normal age class distributions.

A forest of even-aged stands can be presented as a system consisting of two basic parts. The first, smaller in area, consisting of mature stands in which regeneration felling is carried out, and yield of the main revenue is realized. The second part of the forest are stands where tending is done through intermediate cuts, and the yield of the previous revenue is realized. Between the two parts, continuous flows of the stands are going on. The regeneration cuts reduce the mature stand area, increasing the areas with intermediate cut stands. Over time, the stands nearest the mature ones, pass into the mature stand forest parts, enhancing their area.

This dynamic system can be presented with the following verbal model:

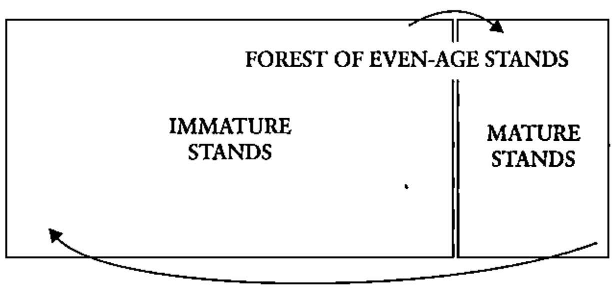


Figure 1. Model of forest of even-aged stands
Slika 1. Model regularne šume

With higher intensity of regeneration felling (ha/year) the young stand area will grow, which means a positive (+) direction of influence. The bigger immature stand area, the higher transition intensity (ha/year) of the stands toward the parts of mature stands, which means a positive (+) direction of influence. Likewise, the higher intensity of stands transition, the smaller the immature stands area, which means the negative (-) direction of influence. The global indication of the causal relationship is negative (-), and the feedback loop's (FBL) polarity is negative. A higher intensity of stand transition from the immature stands parts will cause an increase in the mature stands area. The bigger mature stands area, the higher intensity of regeneration felling, i.e. a positive (+) direction of influence. The area of mature stands ready for felling will decrease with the rise in the regeneration felling intensity. This means a negative direction of influence. The global indication of the causal relationship is negative (-), and the feedback loop's polarity is negative (Fig. 2).

The normal state of forest of even-aged stands is based on a series of stands of various ages. Therefore, forest of even-aged stands should be presented as a system composed of a series of age classes, independent of their number or width. This even-aged forest model can be expanded and represented with the following verbal model:

The transition of stands into a first age class (ha/year) depends on the regeneration felling policy (major harvest cut). Over time, regeneration can be constant or variable.

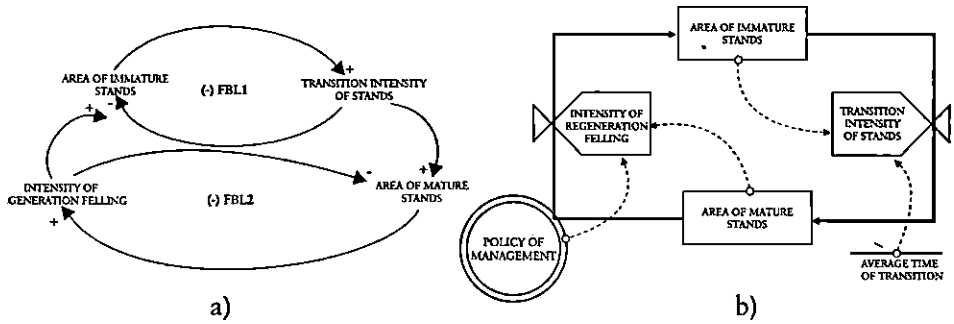


Figure 2. a) Structural model of forest of even-aged stands
b) Elementary diagram of flows
Slika 2. a) Strukturni model sustava regularne šume
b) Elementarni dijagram tokova

The more intensive the regeneration, the bigger area in the first age class will be, which means a positive (+) direction of influence. The bigger area in the first age class is, the more stands area will move from the first into the second age class (hectare annually), which again denotes a positive (+) direction of influence. At the same time, the stands area in the first age class will be smaller as more stands area move from the first into the second age class, which is a negative (-) direction of influence. A more intensive transition of stands area from the first into the second age class will lead to an increased stands area in the second age class (a positive (+) direction of influence), which will in turn cause a bigger stands area to pass from the second into the third age class (again a positive (+) direction of influence). With a more intensive transition of stands area from the second into the third age classes, the stands area in the second age class will be smaller (a negative (-) direction of influence).

The series of influences continue in the same manner and its length depends on the number of age classes, that is, on the rotation.

The stands area in the last age class will be bigger if the transition of stands from the penultimate age class is faster (positive (+) direction of influence); it will be smaller if felling intensity in the last age class is higher (negative (-) direction of influence).

This verbal model of an even-aged forest dynamic system can be presented with the extended influence diagram and an elementary diagram with flows (Čavlović 1996).

The functioning model of the even-aged forest management process consists of the state variables connected by processes into a dynamic system where there are causal relationships and the feedback loop's. The state elements are the areas of the individual age classes in each time section, i.e. in each interaction period the changes in the individual flows are summed.

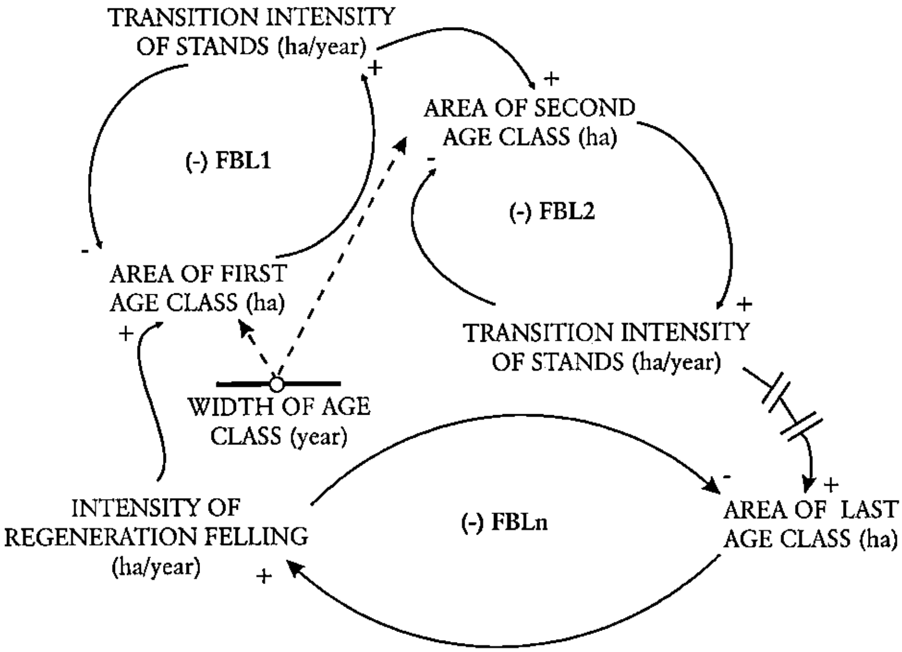


Figure 3. Extended structural model of forest of even-aged stands
Slika 3. Prošireni strukturni model sustava regularne šume

The state variables are calculated using the following formula:

$$\text{New state} = \text{old state} + \int_{t_0}^{t_1} (\text{input changes} + \text{output changes})\,dt \qquad (1)$$

The equation of the state in the DYNAMO simulation language:

$$L\ L.K = L.J + (DT) \times (RA.JK - RS.JK) \qquad (2)$$

The presented model of the even-aged forest management process is a closed system with a self-regulating character. Its behavior will depend on external impacts that can be defined by control equations. In the mentioned model, the regeneration felling policy, which decides on the regeneration felling practice, has been taken as a powerful control mechanism on which the behavior of the given even-aged forest will depend over a long time period. With defining the felling policies and rotation length, the system dynamic simulation may investigate the most suitable management of the real forest under particular conditions.

The methodology consists of the DYNAMO (DYNAmic MOdeling) simulation language, programming and computer simulation in BASIC-version, use of the SYSDYNS (system dynamic software package), and the DYNAMO language in BASIC enabling computer simulation (Forrester 1992, Munitić 1990).

THE OBJECT AND AIM OF SIMULATION RESEARCH
PREDMET I CILJ SIMULACIJSKOG ISTRAŽIVANJA

The simulation research was targeted at the management class of pedunculate oak in the management unit "Lacic Gložđe". The management class consists of pedunculate oak stands in the first quality site class. The total area of the management class is 3,223.88 ha, the total growing stock is 989,057 m^3 and the measured annual increment is 29,409 m^3 (10.20 m^3/ha). Compared to the normal age class distribution, there are a surplus of midle aged understocked stands and deficite of mature and young stands. (Table 1, Figure 4, 5)

Table 1. Data of real forest of even-aged stands (Management class of pedunculate oak-Management unit "Lacić Gložđe").

Tablica 1. Podaci stvarne regularne šume (Uređajni razred hrasta lužnjaka-Gospodarska jedinica Lacić Gložđe)

	AGE CLASS							Total
	0-20	21-40	41-60	61-80	81-100	101-120	121-140	
	years							
Actual area (ha)	353.24	59.64	591.24	783.46	1325.82	110.48		3223.88
Normal area (ha)	460.55	460.55	460.55	460.55	460.55	460.55	460.55	3223.88
Actual growing (m^3) stock (m^3/ha)	- -	12,167 204	157,861 267	241,306 308	532,980 402	44,744 405		989,057 307
Norm. growing (m^3) stock (m^3/ha)	- -	65,859 143	129,875 282	184,681 401	220,603 479	244,552 531	259,290 563	1,104,859 343

Figure 4. Real and normal age class distributions per area

Slika 4. Stvarna i normalna dobna struktura po površini

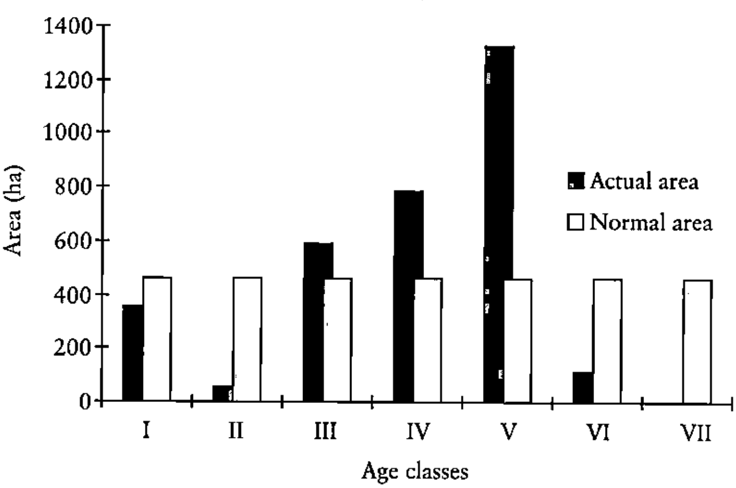
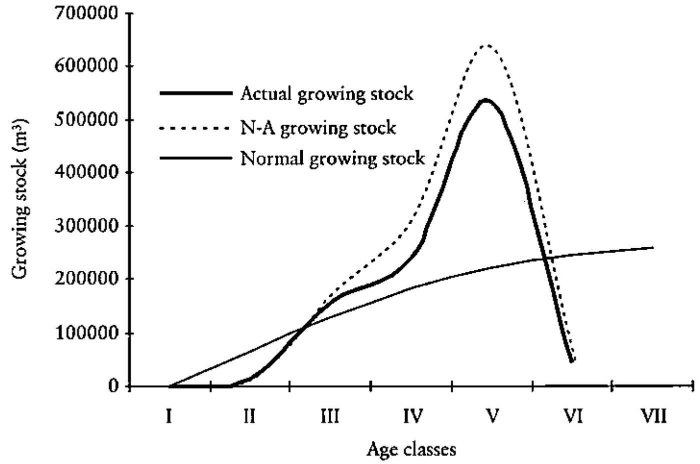


Figure 5. Real and normal age class distributions per growing stock
Slika 5. Stvarna i normalna dobna struktura po drvnoj zalihi



N-A growing stock (g.s. based on the real age class distribut. per area and normal stocked stands)

The surveyed and classified data present the initial states in the course of simulation research on the behaviour of the given even-aged forest system.

The aim of the research was to estimate:

- future development of age class distribution per area and growing stock;
- time needed to equilize age class areas;
- trends in the total growing stock and annual felling and intermediate cut within the defined management requirements;

THE RESULTS OF SIMULATION RESEARCH
REZULTATI SIMULACIJSKOG ISTRAŽIVANJA

THE DEVELOPMENT OF AGE CLASS DISTRIBUTION
KRETANJE RAZMJERA DOBNIH RAZREDA

The simulation was conducted on the sample of actual age-class data (area, actual growing stock per hectare and achievement of a normal growing stock per hectare).

The management policy scenario was based on a 140-year rotation period, according to which regeneration felling is carried out in mature stands in an area representing the rth part of the total forest area. In the course of the simulation period, no changes in the total forest area have occurred, neither by increasing it through afforestation, nor by reducing it, so that the felling intensity has remained constant for the whole simulation period (Eq. 3).

$$IRF = \frac{A}{r} = constant \qquad (3)$$

where IRF - intensity of regeneration felling (ha/year)
A - total (unchangeable) forest area (ha)
r - rotation in years

With regard to the rotation length, a model was studied within the defined scenario according to the dynamics of the age class distribution behaviour along a particular time axis. In connection with trends in the age class distribution (Fig 6), there was a specific flow of the total growing stock and annual cuts (Fig 7).

Figure 6. Trends area of age classes
Slika 6. Kretanje površine dobnih razreda

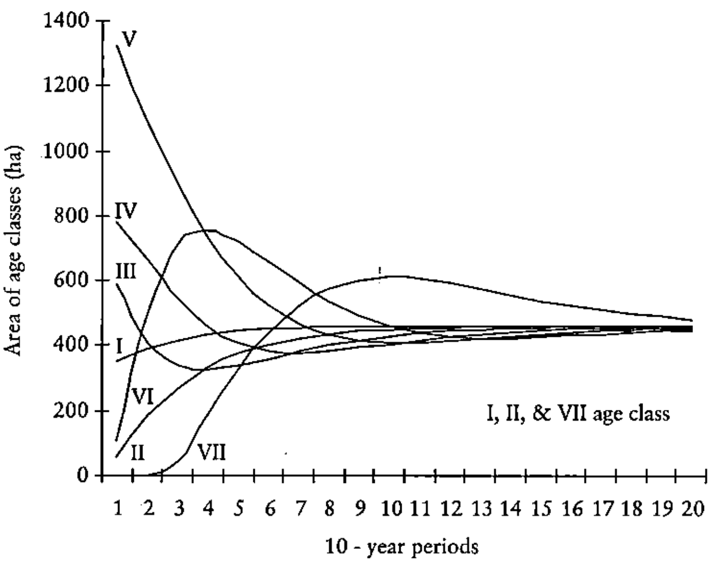


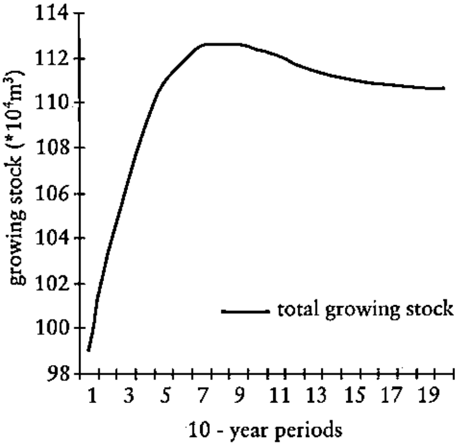
Figure 6 shows the development of age class distribution over a period of 200 years. As can be seen, the age class distribution did not achieve a normal age class structure within the mentioned period.

The greatest changes occurred in area trends of the three last age classes. There is considerable between the last age class distribution and other age classes. The amounts and intensities of these changes over time, particularly of the first and last age class are significant for long-term even-aged forest management.

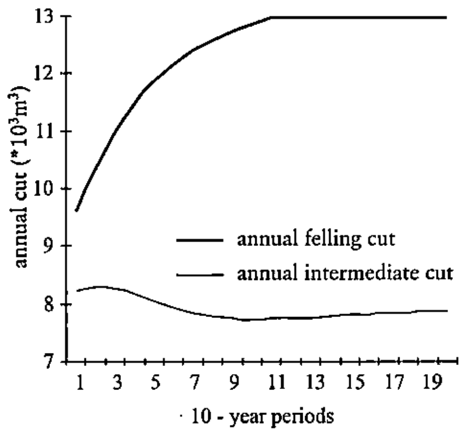
Trends in the total growing stock are the consequence of trends in age class distributions and of the achievement of normal stand stocking. Changes in the trends

Figure 7. Trends of a) total growing stock
b) annual cuts

Slika 7. Kretanje a) ukupne drvne zalihe
b) godišnje sječe



a)



b)

of growing stock and annual cuts were more intensive in the first part of the simulation period which was characterized by equilization.

CONCLUSION
ZAKLJUČAK

Model-building and simulation supported by system dynamics may illustrate complex forestry systems such as those of the even-aged forests managed by the method of age class distribution. Computer simulation models may simulate the behavior of actual even-aged forest systems within a particular period for determining their future development. The method is an integral support to the process of management and planning in forestry, both at local and higher management levels.

According to the assumed management, the initial state of the age class distribution, and the state of the increment and growing stock in any real forest of even-aged stands, the suggested ongoing simulation model can determine the future development of the age class distribution and the flow of the cut and growing stock.

System dynamic modelling makes it possible to build into the simulation model future assumptions of the changes that may affect forest resource management of a particular region. According to the obtained behavior dynamics in the studied system, as response to the simulated scenario, a long-term planning of physical, economic and financial elements is possible.

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SUSTAV DINAMIČKI MODEL REGULARNE ŠUME

SAŽETAK

Temeljni je zahtjev koji se danas postavlja pri gospodarenju šumskim resursima trajna proizvodnja svih koristi od šume uz očuvanje stabilnosti šumskih ekosustava. Razmatrajući gospodarenje regularnim šumama, taj će zahtjev biti osiguran postizanjem strukture normalnih i stabilnih šuma koja se zasniva na normalnom razmjeru dobnih razreda. Kako je riječ o prirodnim sustavima u kojima vladaju vrlo složeni odnosi u vremenu i prostoru, za metodu je rada upotrijebljen sustav dinamičko modeliranje, pri čemu je projektiran simulacijski model procesa gospodarenja regularnom šumom uz primjenu metode razmjera dobnih razreda.

Nakon simuliranja odgovarajućih scenarija istraživanje je usmjereno na budući razvoj razmjera dobnih razreda po površini i drvnoj zalihi u gospodarskoj jedinici Lacić Gložđe unutar uređajnoga razreda hrasta lužnjaka.

Simulacijskim je istraživanjem utvrđeno da su pri uređivanju regularnih šuma određivanje intenziteta oplodne sječe (način određivanja površinskoga etata glavnoga prihoda) te duljina ophodnje vrlo značajni čimbenici koji utječu na buduće ponašanje zatvorenoga sustava regularne šume (promjene u kretanju razmjera dobnih razreda, površinskoga etata glavnoga prihoda, drvne zalihe, vrijednosti šume).

Ključne riječi: potrajno gospodarenje, regularna šuma, sustavna dinamika, razmjer dobnih razreda

UDK: 630*305+377

Original scientific paper
Izvorni znanstveni članak

TEAMWORK IN THINNING STANDS OF THE POŽEGA MOUNTAINS WITH SPECIAL REFERENCE TO TRACTOR SKIDDING

SKUPNI RAD PRI PROREDAMA U SASTOJINAMA POŽEŠKOGA GORJA S POSEBNIM OSVRTOM NA PRIVLAČENJE DRVA TRAKTORIMA

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This study presents the findings of an investigation on teamwork, which was defined as a group of people working on the same production task at the same time and in the same place. Work and time study served to establish the productivity of a group and to determine standard time and efficiency. The study also includes an investigation of the costs for every individual worker and for the entire group of workers in three different models applied on two work sites. These investigations were carried out in the mountainous region of the Forestry Management of Požega, in the forestry offices of Kutjevo and Pleternica.

The standard time of the Torpedo tractor ranges from 23.94 min/m^3 to 41.81 min/m^3 and that of the Ecotrac from 25.35 min/m^3 to 59.07 min/m^3. The daily performance of the Torpedo tractor ranges from 20.05 m^3/day to 11.48 m^3/day at distances of 50 m to 600 m and from 11.48 m^3/day to 8.43 m^3/day at distances of 50 m to 450 m. The performance of the Ecotrac ranges from 18.93 m^3/day to 11.71 m^3/day and from 14.60 to 8.13 m^3/day at distances of 50 m to 550 m.

At the Kutjevo work site, the total cost of the first pair (model 3 - cutters and tractors) amounted to 97.75 kn/m^3 and that of the second pair 103.28 kn/m^3. Compared to model 1, these costs were lower by 39.7% and 42.1% respectively and compared to model 2 by 23.4% and 29.7% respectively. The total costs incurred in model 1 at the Pleternica work site amounted to 163.35 kn/m^3 for the Torpedo tractor and to 226.43 kn/m^3, or 27.9% more, for the Ecotrac. The costs related to the Ecotrac were 28.1% higher in model 2 and 30.2% higher in model 3 compared to the costs related to the Torpedo.

Teamwork has been partially accepted as a practice in Croatian forestry and has helped to improve productivity. However, the results of the study point to an imperfect organisation of teams and to a need for them to be optimised.

Key words: teamwork, cutting and processing, skidding, timber inspection, standard time, daily output, costs.

INTRODUCTION
UVOD

According to Ugrenović and Benić (1957), the utilisation of forests is a production process encompassing the entire work invested for the purpose of producing and using the material goods of forests.

Human labour has been used extensively in forest exploitation, cutting, processing and transporting. In the past, transporting operations were first carried out by manpower and then by animal power. With the emergence of machines, manpower was replaced by mechanical power. This process of replacing power is almost complete in developed countries. Nevertheless, the developing and particularly the underdeveloped countries still use man and animal power and gravitation in addition to machines.

Most forestry workers work in the exploitation of forests and the resulting operational costs are very high. However, the entire costs of production, machines and roads must be regarded as a whole, as a single system. The exploitation of thinning stands accounts for a significant part of the entire activities of forestry exploitation in Croatia.

The choice of work technology for the exploitation of forests constitutes a significant problem and so does the choice of machines which partially determines the work technology. On the basis of an analysis of sustainability and of the ratio between the dominant and intermediate yields, an assessment is made of the machines to be applied and of the conditions in which they can be used.

Significant progress has been made in the exploitation of forests with the use of power saws for cutting and processing and tractors for skidding. In log skidding, the assortment method was abandoned and the shortwood, longwood and tree-length log methods of processing were introduced. Every method is adapted to the size, power and capacity of individual machines and to the conditions in the stands.

Apart from appraising the technical, productive and ergonomic characteristics of tractors, account must be taken of their environmental performance. Particular attention must be given to the possible damage to trees, to soil erosion, to an adequate level of training of the machine operators in issues relating to forestry, including technical and environmental issues.

Forest exploitation must be based on ecology, on an increased humanisation of labour and on minimising the costs of carefully selected optimal methods of work.

The use of tractors in forest exploitation reduces the role of human labour, allows for more accurate planning, aims at optimising production, leads to better performance, and reduces the cost of work.

THE PROBLEM AND THE AIM OF THE STUDY
PROBLEMATIKA I CILJ ISTRAŽIVANJA

Since the very beginning of his days, man has exploited forests in different ways and with different intensity. At first he used his own power and then began to rely on animal power. For timber logging, man also used the natural configuration of the terrain, gravitation and water flows.

In the 18^{th} century, man started to apply different machinery for the exploitation of wood.The first mechanical skidding of wood was carried out by cableways of hemp cable in 1825 in Sorrento, Germany (Krpan 1995). The cutting and processing was done with axes and handsaws. Logs were predominantly hauled by animal power, using water flows (rivers) and narrow-gauge railway tracks.

According to Benić (1963), forest exploitation consists of two stages: the stage of cutting and processing and the stage of carrying the wood out of the forest after some initial processing. The latter stage consists of two sub-stages: skidding and hauling.

According to Bojanin (1983), forest exploitation encompasses stage 1 (cutting and processing) and stage 2 (transport of wood). The transport of wood is further divided into skidding and hauling.

Krpan (1992) divides forest exploitation into the cutting and processing stage and the transport stage. The transport stage consists of yarding, skidding and hauling. Yarding means moving parts of trees or logs by human, animal or mechanical power from stumps to the site where the load is best prepared for skidding, and this is predominantly done in openings. According to Krpan, skidding means moving parts of trees or logs from stumps or collection sites to an auxiliary landing. Hauling means moving parts of trees or logs from an auxiliary landing to the customers.

With the emergence of machines and their application in forest exploitation, the notion of technology appears, defined by Pampel as the "science of the natural and technical patterns of the material and technical aspects of the production process and its conscious application by people" (Krpan 1984).

According to Bojanin (1971), the introduction of mechanisation constitutes an attempt to increase efficiency, to reduce the labour force, to reduce workers' fatigue to the minimum and to reduce to the highest degree the costs per unit of product.

Bojanin (1983) studied the mechanisation of forest exploitation from two aspects: the working and technological aspect and the economic aspect. In his opinion, the best technical solution does not necessarily have to be the best economic solution. In making these choices, it is important to ensure the best technology and machinery for the given circumstances, but with the most favourable economic aspect. However, it is the selling price and the technical characteristics of a rich variety of different forestry machines that ultimately determine the best choice of technology.

Skidder tractors, which first appeared in Croatia as early as 1951, were crawlers of the Caterpillar and Ansaldo type. The machines began to be introduced on a much larger scale in 1960, when the tractor factories called IMT, BNT and 14th October opened in what was then Yugoslavia. At the time, mass-produced agricultural tractors were used with some additional equipment which enabled them to work in forests.

The development of the third generation of machines (Sever 1980), which were specially designed to function in forests, originated from these agricultural tractors and their additional equipment was adapted for skidding operations.

Special forest tractors (skidders) were employed in Croatia for the first time in 1968, while in Norway they had been introduced as early as 1962. From 1979, an increasing number of articulated wheeler tractors and crawler tractors were introduced (Krpan 1984).

In Croatia in 1991 (Zečić 1996), logs were skidded by 353 adapted agricultural tractors, which accounted for 44.6% of the total skidding vehicles. Out of these, 212 tractors were equipped with winches. There were 13 articulated tractors of up to 35 kW, accounting for only 1.6% of the total number of skidding vehicles, 32 articulated tractors with more than 35 kW accounting for 27.8%, 32 forwarders or 4%, and 173 tractors with semi-trailers or 21.8%. In 1995, the situation changed drastically in favour of articulated wheeler tractors. Therefore, there were only 188 or 35.9% adapted agricultural tractors, 59 or 11.3% articulated tractors of up to 35 kW, 211 or 40.3% articulated tractors of more than 35 kW, 23 or 4.4% forwarders and 43 or 8.2% tractors with semi-trailers.

These machines cause some damage to the stand. The profundity of the compression or the break-up of the soil depends on the extent of the vehicle's pressure on the soil, on the condition of the soil, on the number of tracks and on the volume of the load. When moving over a felling site, an adapted agricultural tractor treads with its wheels on almost 2.5% of the soil, an articulated tractor on almost 5%, while their wheels sink 13.8 to 24.5 cm into the soil (Krpan 1993).

When moving from the trunks toward an auxiliary landing, a tractor damages the standing trees with its load, wheels and body. A tractor can cause more damage by moving in an uncontrolled way on the entire surface than by moving on previously planned tracks or built skid trails. With longwood or tree-length methods (Martinić 1990), there are 9.9% damaged trees in thinned stands. The damaged standing trees have a reduced diameter growth of up to 4.7% (Krpan 1993), they are vulnerable to fungi and their level of exploitation is lower.

The exploitation of thinning stands is affected by the law of production and the law of the diameter of a log, which were termed by Grammel in 1988 as the laws of mechanisation (Krpan 1996).

TEAMWORK IN FOREST EXPLOITATION
SKUPNI RAD U EKSPLOATACIJI ŠUMA

The traditional method of work in the exploitation of forests was too time consuming, since the stages of activity used to be done separately. Several months would pass from cutting and processing to the transportation of the product. In order to increase productivity, a solution had to be found in the improved organisation of work and in the better management of working time.

Depending on the number of workers involved in production, there is individual work and teamwork. Teamwork is defined as a group of people working at the same time and in the same place on the same production task. Such a form of work is carried out through simple or complex cooperation and is characteristic of all the developed forms of production (Krpan 1996).

Workers in a classical exploitation process - cutters, tractor drivers, foremen and district forestry officers - had been accustomed to work separately. With the introduction of the teamwork form of work organisation, they all began to be situated at one work site. A foreman spends the entire day with cutters and tractor drivers and directly manages the entire work, which has an effect on the quality of the work performance. Teamwork enables workers, foremen and district forestry officers to supervise each other. All members in the chain of the organisation have to do their part of the work responsibly.

The working process in teamwork can be adapted very quickly to changes in the cutting plan or to a re-adjusted plan, which ensures that the necessary task will be carried out.

The costs of cutting, processing, skidding and hauling were a decisive factor in favour of the introduction of this new and more rational form of work organisation.

The need for an improved work organisation was based on the high cost of exploitation brought about by the length of the production cycle. Therefore, the aim was to shorten the duration of production as far as possible. In fact, it is indeed possible to cut, cross-cut, buck and skid timber to the auxiliary landing and haul it to the main landing or to the customer in one working day. Such a model of work organisation has actually come very close to the industrial form of production. According to Benić (1971), working operations that take place simultaneously shorten the duration of a working stage or a working process.

Tractors were introduced in forest exploitation in the 1960s, both for skidding and hauling timber. As long as it was economically possible to exploit forests in separate working stages, tractors skidded forest products to the auxiliary landing only after the cutting and processing operations had been finished.

According to Winkler (1990), teamwork in forest production is carried out by crews of workers who separately perform cutting, skidding, hauling, construction work and so on, but they are only formally connected. The second type of crew in teamwork is the one that performs several stages of work, for instance, cutting and skidding. These crews are permanent and the number of their members can vary. The third type is constituted by complex working groups doing all the major forestry management operations. They are permanent and closely connected. With the introduction of machinery in forest production, large groups have tended to become smaller and in this way individual work and all of its negative aspects are avoided.

Teamwork was introduced in Croatia for the first time in 1979 on the territory of the forestry management unit of Bjelovar. In the subsequent 2-3 years, teamwork came to be applied by all forestry offices in the Bjelovar region. In 1984, teamwork also started to be applied in the thinned stands, which gave rise to the need for an increased quantity of tractors.

In the territory of the forestry management of Požega, teamwork was applied for the first time in 1982 during the final cut of durmast oak, in compartment 69 of the Sjeverni Dilj I management unit. In the following years, teamwork was monitored and organised in order to achieve the best structure of the group. In 1995, almost the entire yield cut was felled and skidded by a working group of the then forestry management of Požega, on the basis of teamwork organisation. The remaining small part of the yield was cut by citizens themselves.

CHARACTERISTICS OF TEAMWORK
ZNAČAJKE SKUPNOGA RADA

A working group is a coordinated group of workers organised in such a way as to function as an autonomous unit equipped with necessary working tools and able to carry out a task. The essence of teamwork is to be well concerted in all operations, from the preparation of work to the transportation of forest products to the customer.

The main characteristics of teamwork include: a shared working assignment given to the entire group, collective work at the same work site, shared working tools and resources, the participation of several workers in the performance of a task, adapted work technology, a balanced distribution of the efficiency and of personal income according to the number of working days, collective responsibility for the fulfilment of an assignment, a collective journey to and from the workplace, a balanced distribution of the cost of fuel and lubricants, a balanced distribution of charges and allowances, and the daily presence of a foreman.

ADVANTAGES OF TEAMWORK
PREDNOSTI SKUPNOGA RADA

Apart from the internal co-ordination of activities aimed at a common goal, the advantages of teamwork also include: an increase in productivity without any additional energy input, working capital is tied up for a shorter period, the time required for timber logging is shortened, less bucking is required during processing, losses in bucking and inspection are reduced (small residues, fewer pieces), teamwork can be practised throughout the year with a varying number of members, fresh and sound wood is delivered, improved protection from pests is ensured, the processing of wood is of better quality (with the processing taking place at the auxiliary landing), the work organisation on the site is better, absenteeism is reduced, the connection between cutters and tractor drivers is closer (they work in pairs), the cutting of trees is targeted, the group adapts itself to weather conditions, the cutter binds the load (no binder), the burden lying on the cutter working with a power saw is reduced, a vehicle ensuring timely emergency aid is always present at the work site, the work is humanised by switching workers within a group, the creativity of every group member can be expressed, an individual's personality can be freely developed, individuals are more interested in their work, a less efficient worker tries to catch up with the others and achieves a better output, the capacities of loading and transportation are fully exploited, the commercial effect is increased and the impact of group psychology is very significant.

DISADVANTAGES OF TEAMWORK
NEDOSTACI SKUPNOGA RADA

Disadvantages depend on the form and method according to which a group of workers is organised and on the choice of the technologies for the cutting and processing of wood (the longwood method, the shortwood method or the assortment method). If the group size is fixed and the distances of skidding are smaller, the cutter will do most of the work and the tractor driver will bind the load. In the opposite case, when the skidding distance is greater, the cutter will bind the load and will not have enough work to do. In groups whose size is not fixed, there are no extreme situations or excessive burdens on individual members, but when the group receives a new member there is a problem of adjustment.

THE AIM OF THE RESEARCH
CILJ ISTRAŽIVANJA

The aim of this study was to examine the application of teamwork in the cutting, processing, skidding and inspection of wood in the thinnings of the Požega mountains. The investigation analyses two groups of workers and their performance with regard to three different methods of work organisation.

A time and motion study will establish the productivity of the groups concerned and their time and piece quotas. In addition, the investigation will serve to establish the costs that the three different models that were applied at the two work sites entailed per member and per group.

THE SITE AND METHODS OF RESEARCH
MJESTO I METODE ISTRAŽIVANJA

The Forestry Management of Požega occupies an area of 49,486.11 ha with a total growing stock of 9,001,835 m^3, a mean annual increment of 310,072 m^3 and an average yield cut of 204,194 m^3. It is organised in six forestry offices: Čaglin, Kamenska, Kutjevo, Pleternica, Požega and Velika, with one Machinery and Civil Engineering business unit situated in Požega.

The average cut of the intermediate yield amounts to 58.62% and the best achievement ever was recorded in 1985 with 70.59%. The average dominant yield amounts to 41.38% of the yield cut.

Table 1 indicates that the third and the fourth age class occupy most of the area, namely: the third age class occupies 13,169 ha or 28.19% and the fourth age class 11,164 ha or 23.90%. The last, seventh age class occupies the smallest area, namely: 801 ha or 1.71%.

Table 1. An Overview of Age Classes in the area of the Forest Administration Požega, situation in 1990

Tablica 1. Pregled dobnih razreda na području Uprave šuma Požega, stanje 1990. godine

Age class *Dobni razred*		Growing stock *Drvna zaliha*			
Number *Broj*	Age (years) *Dob (god.)*	ha	%	m^3	%
I	1-20	7 240	15.50	-	-
II	21-40	5 593	11.97	454 100	5.75
III	41-60	13 169	28.19	2 509 300	31.76
IV	61-80	11 164	23.90	2 746 300	34.76
V	81-100	5 225	11.18	1 353 600	17.13
VI	101-120	3 526	7.55	708 900	8.97
VII	121<	801	1.71	128 100	1.62
Total / *Ukupno*		46 718	100.00	7 900 300	100.00

Obviously, most of the growing stock belongs to the fourth age class - 2,746,300 m^3 or 34.76% of the total growing stock. Next follows the third age class with a total growing stock of 2,509,300 m^3 or 31.76% and the seventh age class has the least growing stock - only 128,100 m^3 or 1.62%.

Compartments 46 b and 47 d (Pleternica) are located in the central eastern part of the management unit (Figure 1). The lowest point stands at 170 metres above sea level, where the auxiliary landing is situated and where the unit borders an agricultural plot. The highest point stands at 250 metres above sea level.

The soil in the area covering the lowest point of the compartment at some 250 m above sea level is composed of pseudogleic components on the hills and of pseudogleic loessial soil on clayey marl at a ratio of 0.50 : 0.50. In the upper part of the compartment there is typical loessial and pseudogleic soil, eutric brown soil and carbonate rendzina on clayey marls and sandy clay at a ratio of 0.70 : 0.15 : 0.15.

Figure 1. Pleternica Work site, a 3D Model
Slika 1. Radilište Pleternica, 3D model

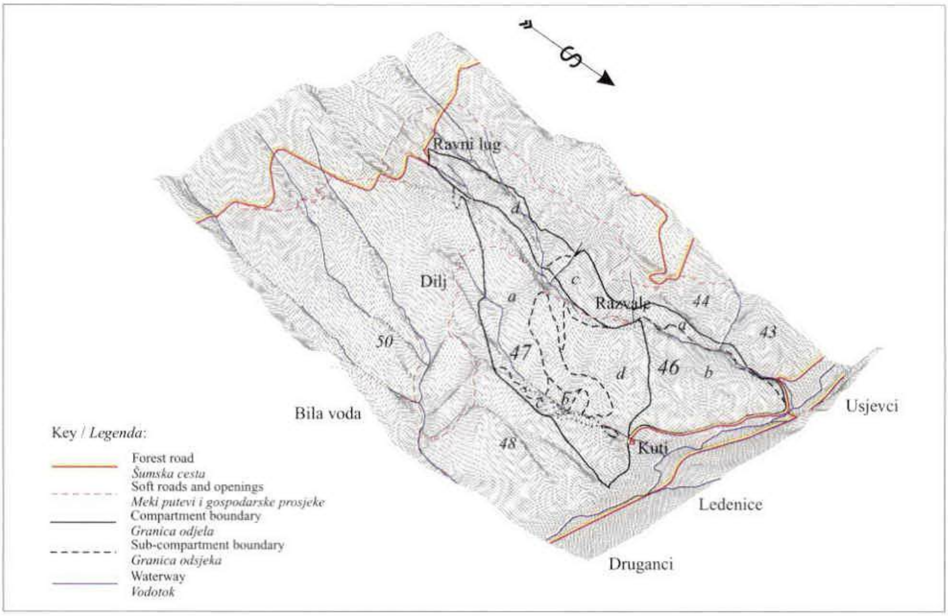
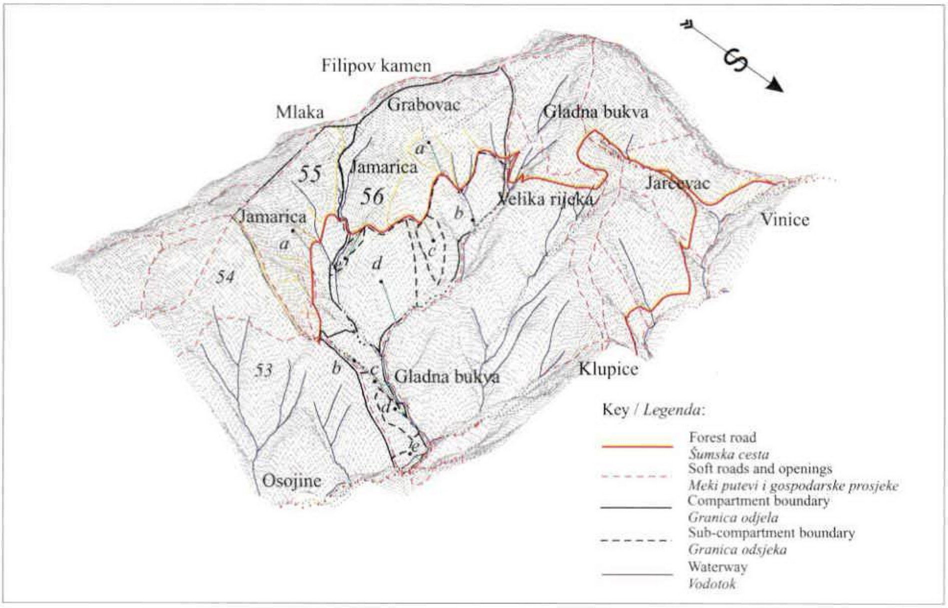


Figure 2. Kutjevo Work-site, a 3D Model
Slika 2. Radilište Kutjevo, 3D model



These two compartments belong to the Illyrian forest of durmast oak and common hornbeam with beech (*Epidemio - Carpinetum betuli* var. *Fagus sylvatica* /Ht. 1938/Borh. 1963).

The basic characteristics of the stand in compartments 55 a and 56 a (Kutjevo) are shown in Table 3. The lowest point of the compartment is situated at 550 m above sea level and the highest at 700 m. The compartments are situated (Figure 2) in the central part of the management unit. A forest road was constructed along the lower boundary of compartment 56 a and across the lower third of compartment 55 a.

FACTORS RELATING TO WORK SITES
ČIMBENICI RADILIŠTA

Factors relating to the habitat at the Kutjevo and Pleternica work sites are presented in Table 2. According to its configuration, the terrain is very even and the average and maximum longitudinal slopes hardly differ at all.

At the Kutjevo work site the air temperatures were very low and there were 2 to 4 cm of snow in the first working week. Throughout the working operation, the soil was predominantly humid.

The factors relating to the Pleternica work site differed considerably from the ones at Kutjevo, because work was carried out in the summer. The morning and daily temperatures were considerably higher than at the Kutjevo work site. The

Table 2. Factors Relating to the Work Site Habitat
Tablica 2. Stanišni čimbenici radilišta

Forest Office *Šumarija*		Kutjevo	Pleternica
Management unit *Gospodarska jedinica*		Južna Krndija I	Sjeverni Dilj II
Compartment, Sub-compartment *Odjel, odsjek*		55 a i 56 a	46 b i 47 d
Soil condition *Stanje tla*		Humid *Vlažno*	Dry *Suho*
Longitudinal terrain inclination *Uzdužni nagib terena*	maximal *maksimalni*	30 %	29 %
	average *prosječni*	12 %	10 %
Air temperature *Temperatura zraka*	morning *jutro*	0 - 11 °C	15 - 20 °C
	day *dnevna*	14 - 20 °C	24 - 33 °C
	average *prosječna*	16 °C	23 °C
Precipitation *Oborine*	rain *kiša*	Occasional, light *Povremeno, slaba*	Short shower, one day *Kratki pljusak, jedan dan*
	snow *snijeg*	2 - 4 cm, 1st week *2 - 4 cm, 1. tjedan*	
Working period *Razdoblje rada*		10. 04. - 12. 05. 1995.	03. - 13. 07. 1995.

soil was predominantly dry. The work was interrupted due to rain only on one occasion for 121 minutes.

FACTORS RELATING TO THE STAND
SASTOJINSKI ČIMBENICI

The factors relating to the stand are illustrated in Table 3. The analysed stand in Pleternica is 15 years older than the one in Kutjevo. The rotation amounts to

Table 3. Factors Relating to the Stands at the Work Sites
Tablica 3. Sastojinski čimbenici radilišta

Forest office *Šumarija*	Pleternica		Kutjevo	
Management Unit *Gospodarska jedinica*	Sjeverni Dilj II		Južna Krndija I	
Compartment, Sub-compartment *Odjel, odsjek*	46 b	47 d	55 a	56 a
Compartment area, ha *Površina odjela, ha*	18.24	18.40	37.92	37.32
Stand age, years *Starost sastojine, godina*	70	70	55	55
Ecological-economic type *Ekološko- gospodarski tip*	II - E - 11	II - E - 11	II - D - 10	II - D - 10
Management class *Uređajni razred*	Sessile oak from seed *Kitnjak iz sjemena*	Beach from seed *Bukva iz sjemena*	Beach from seed *Bukva iz sjemena*	Beach from seed *Bukva iz sjemena*
Rotation, years *Ophodnja, godina*	120	100	100	100
Cover, 0.1 - 1.0 *Obrast, 0.1 - 1.0*	1	1	0.9	0.9
Number of trees, items/ha *Broj stabala, kom/ha*	778	935	1 017	768
Mean tree diametar at breast height, cm *Srednji prsni promjer stabla, cm*	19	20	17	19
Mean stand height, m *Srednja sastojinska visina, m*	19	19	18	21
Mean tree volume, m^3 *Srednji obujam stabla, m^3*	0.538	0.597	0.408	0.595
Growing stock, m^3/ha *Drvna zaliha, m^3/ha*	284	299	200	233
Growing stock, m^3/compartment *Drvna zaliha, m^3/odsjeku*	5 172	5 525	7 596	8 710
Annual current increment, m^3/ha *Godišnji tečajni prirast, m^3/ha*	10.6	9.3	10.9	11.9
Annual current increment in the compartement, m^3/ha *Godišnji tečajni prirast u odsjeku, m^3*	194	172	413	445
Harvesting volume, 10-year, m^3/ha *Etat, 10-godišnji, m^3/ha*	38	40	37	43
Harvesting volume, 10-year, m^3/compartement *Etat, 10-godišnji, m^3/odsjeku*	694	736	1 403	1 605

100 years in all compartments except for 46 b where it is 120 years. The number of trees per hectare is much higher at Kutjevo. The characteristics of intermediate trees are slightly different.

The growing stock per hectare is 1/3 smaller at Kutjevo, but the annual increment at Kutjevo is 100% higher than at Pleternica. The yield cuts per hectare differ only slightly.

FACTORS RELATING TO EXPLOITATION
EKSPLOATACIJSKI ČIMBENICI

The applied method of cutting and the medium distance of skidding ranging from 350 m to 600 m are very important factors defining the work sites. In the structure of wood assortments, the technical roundwood ranges from 23.2% in compartment 55a to 35.5% in compartment 47d.

Table 4. Factors Relating to the Exploitation of Work Sites
Tablica 4. Eksploatacijski čimbenici radilišta

Forest office *Šumarija*		Pleternica				Kutjevo			
Management Unit *Gospodarska jedinica*		Sjeverni Dilj I				Južna Krndija I			
Compartement, Sub-compartement *Odjel, odsjek*		46 b		47 d		55 a		56 a	
Type of *Vrsta*	yield/*prihoda*	Intermediate *Prethodni*		Intermediate *Prethodni*		Intermediate *Prethodni*		Intermediate *Prethodni*	
	cut/*sijeka*	Thinning *Proreda*		Thinning *Proreda*		Thinning *Proreda*		Thinning *Proreda*	
Skidding distance (from OG), m *Udaljenost privlačenja (iz OG), m*		600		350		600		500	
Distance from tree to tree *Udaljenost od stabla do stabla, m*		15.4				10.3			
		m^3	%	m^3	%	m^3	%	m^3	%
Total cuttimber volume *Ukupno posječeni drvni obujam*	Gross *Bruto*	589		478		930		1 629	
	Total net *Ukupno neto*	473	100.0	383	100.0	856	100.0	1 493	100.0
	Technical roundwood *Tehnička oblovina*	154	32.6	136	35.5	199	23.2	389	26.1
	Long stackwood *Višemetar. pr. drvo*	319	67.4	247	64.5	657	76.8	1 104	73.9

ERGONOMIC FACTORS
ERGONOMSKI ČIMBENICI

The processes of cutting and processing are characterised by the noise and vibrations produced by a power saw. During the delimbing operation, the noise next to a worker's ear must not exceed 104 dB (A) (Lipoglavšek 1983). The average level of the daily exposure to noise should not exceed the permitted threshold of 90 dB (A) (Martinić 1990). According to Martinić, in teamwork the range of noise for a cutter working on a felling site is from 97.8 to 102.1 dB (A) and for cutters working at an auxiliary landing it is 101.9 dB (A).

"The vibrations on the handles must not exceed the maximum linear values of acceleration of 50 m/s^2 or the weighted average values (according to ISO) of 12 m/s^2, or the force of transmission to the hands of 20 N" (Lipoglavšek 1983).

Apart from the above-mentioned factors, the shape and the mass of tools are also relevant. The length of the handle and the total mass of an axe are adapted for cutting and driving wedges into wood. The length of the lever used for the rolling of logs is adapted to the average diameter of a log.

Lipoglavšek (1983) observed the noise and vibrations in skidding devices. The intensities of noise differ depending on individual working operations. The level of noise involved in work with a power saw imposes the obligatory use of occupational safety devices. The vibrations on a tractor seat differ significantly depending on individual working operations. An improved adaptation of machines to workers and a good positioning of handles in different types of tractors can help to reduce workers' daily fatigue.

ORGANISING WORK SITES FOR TEAMWORK
ORGANIZACIJA RADILIŠTA PRI PRIMJENI SKUPNOGA RADA

Several preparatory operations need to be carried out in order to successfully organise the cutting of a stand. An analysis of the terrain and the collection of the necessary data are done through teamwork. A district forestry officer, a forestry office manager and an expert on forest exploitation determine the appropriate method of work based on their experience. Next, an elaboration and a calculation are made with regard to the necessary quantities (of cutters and tractors) and it is on this basis that the final decisions with regard to the work technology are made.

When organising work sites, first the preparatory work (an analysis of the cutting plan) needs to be done in the office. On the basis of the determined quantities of tractors and cutters, the required numbers of workers and sizes of groups are defined. The remaining cutters are assigned to other areas to be felled and are given other silvicultural assignments. The next step is to categorise the terrain for tractors. The work order defined for every category of terrain and for the medium distance of skidding.

STRUCTURE OF A WORKING TEAM AND ITS INTERNAL ORGANISATION
STRUKTURA SKUPINE RADNIKA I UNUTARNJA ORGANIZIRANOST

A working team was composed of a certain number of cutters and tractor operators over whom a foreman was appointed. The selection of the team members (cutters and tractor drivers) was made by the foreman, the district officer, the officer for the exploitation of forests and the forestry manager. Several factors were considered when forming the team: the general ability of the cutters, their age, previous work results, their place of residence, knowledge of tractors, and/or certificates of occupational qualifications. The socialisation of the individuals within the team depended on the mutual relationship of the members and on the personality of each individual. In each crew at least one cutter also had to possess qualifications as a tractor driver, so that in the case of the absence of one of the tractor drivers, the cutter would be able to operate the tractor. The same condition applied to tractor drivers: at least one had to be trained to work as a cutter, in order to be able to substitute at felling.

When the team was at work, the workers did not alternate regularly in carrying out different operations, but an exchange took place only if one of the workers was absent.

Cutters changed places at regular intervals only at the auxiliary landing. Each month a different cutter would work at the auxiliary landing. The exchange was done to balance the burden imposed on each cutter and on the power saw, that is, on the saw chain, chain sprocket and chainsaw blade. The cutting mechanism of the power saw would wear out more easily when the cross-cutting was carried out at the auxiliary landing due to the mud or dust that would collect on the skidded timber.

THE FOREMAN
POSLOVOĐA

In teamwork, the presence and qualifications of the foreman are of great importance. The foreman of a team is proposed by the district officer, and the decision is confirmed by the forestry manager. Among the available forestry technicians, those who are relatively young, technically well trained, possess a driving licence, have more than five years of work experience, are appropriately creative, and have good managerial and communication skills are usually selected.

The foreman's tasks are: micro-organisation at the work site, the inspection of processed wood assortments, the quality control of felling, processing, skidding, sorting and the delivery of wood assortments, marking the tractor trails before they are constructed as well as the skid trails during work, being responsible for safety at the work site, taking control of the small cultivation operations carried out by the cutters during felling and processing, keeping records of work attendance, doing the monthly wage accounts, writing monthly reports for each worker and each working tool, ordering spare parts and operating supplies, fuel and lubricants, communicating regularly with the district officer, etc.

THE KUTJEVO WORK SITE
RADILIŠTE KUTJEVO

At the Kutjevo work site, there was a group of five workers: three cutters and two tractor operators. The workers assembled at the auxiliary landing. The cutters and the foreman arrived by mini-bus, and the tractor operators drove the tractors every day from the parking place to the felling site, which took them about 30 minutes. At the end of their work, they would drive back to where the mini-bus was parked. The cutters would arrive earlier, attend to their tools and working equipment and wait for the tractors to arrive.

The cutters would ride on the tractors from the assembly point to the felling site; at lunchtime they would ride to the lunch site, and after lunch they would return to the felling site by tractor. With the last ride they would return from the felling site to the assembly point.

This team, according to the working order and the calculated workforce of 5.66 and 5.68 workers, was planned to consist of 5 members. The assumed efficiency was as much as 120%. Due to the expected frequent tractor failures, the transfer of workers from one team to another was arranged according to cutting priority.

With such an organisation of teams, two cutters were cutting in the forest, while a third cutter worked at the auxiliary landing. This was done as pair work, since each cutter worked with one tractor, prepared a sufficient quantity of wood for each load and almost for every cycle helped the tractor operator bind the load.

THE PLETERNICA WORK SITE
RADILIŠTE PLETERNICA

At this work site, a team made up of two cutters and two tractor operators, led by the foremen, arrived by mini-bus at the same time. The number of workers in this team was determined by the number of working tractors and by the number of cutters available. According to the working order and the efficiency per tractor without a choker, 3.71, or 3.83 workers were needed in the team.

In the morning, the tractor operators checked the tractors (fuel, oil, equipment), while the cutters prepared the power saws and other equipment. After this preparation, the tractors would drive to the felling site, taking the cutters and their working equipment.

At the felling site, one of the cutters selected and cut the trees. Meanwhile, the other selected a place to put the fuel, lubricants and other equipment, and then carried out the cross-cutting and inspection of wood assortments in the presence of the foreman. Both cutters from time to time bound the load with the tractor operator.

At the end of the working day, the trees were cut and processed for the first cycle on the following day. In this way, the tractor operators could start forming and skidding the load for the first cycle as soon as they arrived at the felling site, without having to wait for the load. At the felling site, the tractor drivers positioned themselves next to one another, consulted each other about the binding of the processed wood assortments, and agreed with one another not to leave any processed pieces. The loaded tractor would then head for the auxiliary landing. At the auxiliary landing the tractor operators separated and sorted the assortments by species of wood and type of assortment, and when the last piece was unloaded, they would do the piling.

BUCKING AND INSPECTION OF WOOD ASSORTMENTS
PRIKRAJANJE I PREUZIMANJE DRVNIH SORTIMENATA

Depending on the method of cutting and processing, the wood assortments are generally bucked at the felling site or at the auxiliary landing. If the assortment method is used, the bucking and processing of wood assortments is done at the stump, and the measuring and inspection, depending on the number of workers in the team, are done at the log landing area or at the auxiliary landing.

In the shortwood and longwood harvesting method, the bucking and inspection of wood assortments are carried out by the foreman with one cutter at the auxiliary landing.

A team of 5 workers operated at the Kutjevo work site. Two cutters cut the trees and processed the wood assortments at the felling site, while a third cutter worked with the foreman at the auxiliary landing, bucking, cross-cutting, measuring and setting plastic boards on the technical roundwood.

Both the shortwood and the assortment method of processing were used. The foreman at the auxiliary landing would sometimes buck, but mostly only measure the volume and carry out inspection. The longwood method was applied only along the tractor skid trails or in the vicinity of the auxiliary landing.

At the auxiliary landing, the foreman generally approaches the loaded tractor that has just arrived and separates the long stackwood from the technical roundwood. A cutter uses the power saw to cross-cut, and the tractor continues skidding the technical roundwood through the auxiliary landing to the unloading area where the foreman bucks the assortments. In the unloading area, the tractor operator normally more down from the tractor and unfastens the load. The previous load is piled by the next tractor to arrive after the wood assortments have been inspected.

At the Pleternica work site, four workers formed the crew: two cutters and two tractor operators, with one foreman. The bucking, processing and inspection of wood assortments were carried out at the stump. The cutter, after cutting and delimbing the tree, separated the commercial timber from the stackwood by cross-cutting. After that, he measured and processed the long stackwood of 4 to 6 metres in length. After the cutter had cut, delimbed and cross-cut several trees, thus producing stackwood, the foreman would come with the timber-inspection book and the equipment for the measuring,bucking and numbering of commercial timber (calipers, measuring device and the complete equipment for plastic boards). The foreman measured and bucked the commercial timber, and the cutter immediately carried out the cross-cutting. After cross-cutting, the cutter would put down the power saw and take the callipers and the measuring device and measure each assortment, while the foreman would register the obtained data in the timber-inspection book. Based on the measurement data and also on the quality of the logs, the foreman then establishes the assortment and quality class, and selects the colour of the marking board. After the inspection of all the pieces of commercial timber from one tree, the time comes for the stackwood to be inspected. Long stackwood lengths are predetermined, so only the diameters need to be measured. The foreman registers into the timber-inspection book the diameter of each piece. When one tree is completed, the second, and the third are processed, and as many trees are bucked as are needed so that the tractor does not have to wait for processing. At the end of the working day, the foreman prepares the necessary number of wood assortments, so that the next morning the tractors can start skidding without delay.

A MEASURING AND DATA PROCESSING METHOD
METODA SNIMANJA I OBRADA PODATAKA

During work and time study in the exploitation of forests, time consumption data are measured with a mechanical or digital chronometer. Common measuring methods are the continuous and repetitive timing methods. Both these methods have their advantages and disadvantages, but in practice, the repetitive chronometer method is used more frequently.

Taboršak (1987) recommends the repetitive method, but reveals the following disadvantages: the measurers need more training, the measurer needs more concentration, a specially constructed chronometer is needed, losses occur as a result of having to return the hands to the starting position, etc. The advantages are: irregularities in work as well as justified pauses are immediately spotted, there is no subsequent calculation of individual times, measuring can easily be continued if it is interrupted for any reason, and, finally, this method allows for the possibility of reading very short operations.

Barnes (1964) makes a preference for the repetitive method because each operation is seen on the observer's chart, so the measurer and the analyst can, during the measuring process, notice differences in each working operation.

For all these reasons, the repetitive timing method has been used in these studies.

DATA PROCESSING
OBRADA PODATAKA

The data were processed on a personal computer at the Institute for the Exploitation of Forests of the Faculty of Forestry in Zagreb. All the data on time measurement and on wood volume were transferred from the observer's charts into the computer. Using existing programs, Microsoft Word, Excel 5.0, Corel 7.0 and Autocad 13(R), these data were thoroughly processed. The map and photographs were printed on an HP DeskJet 560 C printer, and the text on an HP LaserJet IIIp printer.

The observation charts were processed twice. Each measurer at the end of the working day made a sum of the measured times and compared them with the time measured on a wristwatch, and established the difference in time and the validity of each observation chart, depending on whether it exceeded the allowed margin of error. The second time, the observation charts were processed after entering the data into the PC, and before the beginning of further data processing.

TIME STRUCTURE
RASPODJELA VREMENA

The time structure used in Croatia is similar to time structure applied in other European countries. In Germany, time and motion studies in forestry started in 1912, when the Max-Planck Institute (the former Kaiser-Wilhelm Institut für Arbeitspsyhologie) was founded. The Association for Work Studies (Verband für Arbeitsstudien REFA e. V.) was founded in 1924 (Krpan, 1984).

In 1956, Samset carried out a detailed time management working scheme in the exploitation of forests. In this work, time management was adapted to the forms of work organisation. By analysing working operations in the production process of the felling, processing and skidding of timber by tractor and by using teamwork, a time management scheme was devised in which the tractor drivers and the cutters cooperated with one another.

The total of measured times can be divided into effective time and delay time. Effective time consists of time spent directly in carrying out the work order (in producing a production unit).

Effective time spent at felling and processing is divided into tree and assortment time. The time that the cutter spends in binding the load was analysed as part of the effective time of the tractor working at the felling site. The effective time of the tractor cycle can be divided into fixed and variable times (Bojanin, 1980). All the times that are not functionally connected with the skidding distance are called fixed times. The time taken in driving a loaded and unloaded tractor is called variable time because it depends on the distance that has to be covered.

Delay time is all the time of rest and sporadic work which is not carried out in a cycle. Delay time, according to Bojanin (1977) and REFA (1976), consists of time for the interruption of work, time for rest and preparation-completion time. Interruption time can be both justified and unjustified. Justified interruptions are all those that are necessary to carry out the set task. Unjustified interruptions are all those that happen consciously or unconsciously, and which do not directly serve the purpose of completing the task. Sporadic work exists outside the regular cycle and is not considered as an interruption in the full sense of the word.

Preparation-completion time is part of delay time. The preparation time comprises the arrival of the tractor drivers from the transport vehicle to the tractor and the preparation of the tractor until its departure to the felling site. Completion time consists of all the time spent in putting the tractor away, and for the driver to get ready and return to the transport vehicle.

A break is an interruption which serves to restore energy. Forestry workers take a break spontaneously when they feel tired. However, the time and duration of the break can be determined in advance. Interruption time for personal needs usually coincides with the break, so it is difficult to determine clearly the specific type of interruption. Therefore, in this work these times have been shown as one.

Respite is a short break which workers take after a very strenuous task. In this study it has not been dealt with separately, because after effective work, the workers always took longer breaks.

A lunch break is 30 minutes long and is established in advance (Taboršak, 1987). The time necessary to arrive at the lunch site and go back to work is calculated within this time.

Time that concerns technical interruptions can be accepted in two ways, as justified or unjustified. If the interruption occurs due to a minor fault of the tractor or working equipment, then we can regard it as a justified interruption. However, if the cause is a tractor breakdown that occurs due to bad and irresponsible handling, then we regard this as an unjustified interruption.

STATISTICAL ANALYSIS
STATISTIČKA OBRADA

Mathematical statistics programs usually applied in the study of time management were used for the statistical processing of the measurement data. For each work operation of fixed time, the required statistical measurements were calculated.

For fixed times:

1. Arithmetic mean

$$\overline{x} = \frac{\sum x_i}{n}$$

2. Standard deviation

$$s_x = \sqrt{\frac{(x_i - \overline{x})^2}{n-1}}$$

3. Standard error of the arithmetic mean

$$s_{\overline{x}} = \frac{s_x}{\sqrt{n}}$$

4. Percent error of the arithmetic mean

$$p = \pm \frac{s_{\overline{x}}}{\overline{x}} 100 \ (\%)$$

5. Required sample size for a 5% error of the arithmetic mean with a probability of 95%

$$N = \frac{1.962 s_x^2}{0.0p^2 \overline{x}^2}$$

where in the expressions:

$\overline{x}$ - arithmetic mean (aritmetička sredina)

s_x - standard deviation

$s_{\overline{x}}$ - standard error of the arithmetic mean

p - percent error of the arithmetic mean, %

N - required sample size for a 5% error of the arithmetic mean with a probability of 95%

x_i - individual sample value

n - size of the measured sample

Variable times are equalised through regression equations of the line and the parabola, and, based on the strength of correlation, a regression line was chosen for the line: $y = a + bx$, and for the parabola: $y = a + bx + cx^2$.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

CUT, PROCESSED AND SKIDDED LOGS
POSJEČENO, IZRAĐENO I PRIVUČENO DRVO

The felling of trees at the Kutjevo work site is generally carried out in two periods. The first felling is carried out before the vegetation period, for the spring period, and the second from 1st to 15th July for the summer working period. The felled trees are processed by the cutters from the respective crew. The felling of trees is directed. A certain number of trees along the tractor trails are not felled in the first felling period, but later when the whole team is working. At the Pleternica work site the cutting and processing of trees is carried out simultaneously, followed by bucking and inspection at the stump, and immediately after that, tractor skidding takes place.

TIMBER VOLUME OF CUT TREES
DRVNI OBUJAM OBORENIH STABALA

The mean breast-height diameter of the felled trees amounted to 20.7 cm, the mean height of trees was 16.2 m, and the mean volume of trees 0.324 m^3. The total volume of large wood at the felling site amounted to 987.85 m^3. In the total number of felled trees (3047), 24.32% leant on the crowns of standing trees.

PROCESSED WOOD FROM PREVIOUSLY FELLED TREES – KUTJEVO WORK SITE
IZRAĐENO DRVO IZ UNAPRIJED OBORENIH STABALA – RADILIŠTE KUTJEVO

The processing of felled trees began six days after the felling had been completed. It was carried out by the cutters from the same team that had cut the trees. In

Table 5. Data on the trees processed by cutters working alongside Torpedo and Ecotrac tractors on the Kutjevo work site

Tablica 5. Podaci o stablima koja su izradili sjekači uz traktore Torpedo i Ecotrac na radilištu Kutjevo

Processed timber components *Sastavnice izrađenog drva*	Cutter with Torpedo tractor *Sjekač uz traktor Torpedo* * - x - **	Cutter with Ecotrac tractor *Sjekač uz traktor Ecotrac* * - x - **
Processed trees, pieces *Izrađena stabala, kom*	240	246
Distance from tree to tree, m *Udaljenost od stabla do stabla, m*	7.65	8.75
	Technical roundwood *Tehnička oblovina*	
Number of pieces *Broj komada*	250	134
Processed volume, m³ *Izrađeni obujam, m³*	51.26	27.84
Diameter, cm *Promjer, cm*	17 - 25.5 - 51	15 - 26.8 - 45
Length, m *Duljina, m*	2 - 4.4 - 9	2 - 3.6 - 8
Piece volume, m³ *Obujam komada, m³*	0.076 - 0.205 - 0.817	0.045 - 0.208 - 0.610
	Long stackwood *Višemetarsko prostorno drvo*	
Number of pieces *Broj komada*	281	371
Processed volume, m³ *Izrađeni obujam, m³*	27.82	48.75
Diameter, cm *Promjer, cm*	8 - 15.2 - 42	9 - 17.6 - 38
Length, m *Duljina, m*	2 - 5.0 - 12.7	2 - 5.2 - 12
Piece volume, m³ *Obujam komada, m³*	0.016 - 0.099 - 0.554	0.031 - 0.131 - 0.482
Total volume, m³ *Ukupan obujam, m³*	79.08	76.59

* Minimal value x Total or mean value ** Maximal value
* *Najmanja vrijednost* x *Ukupna ili srednja vrijednost* ** *Najveća vrijednost*

Table 5 we can see that the cutter working alongside a Torpedo tractor (first cutter) processed 240 pieces, while the one working alongside an Ecotrac tractor (second cutter) processed 246 trees. The first cutter processed 250 pieces of commercial roundwood of a total volume of 51.26 m^3, a mean diameter of 25.5 cm, a mean length of 4.4 m, and a mean volume of 0.205 m^3. The second cutter processed 134 pieces of commercial roundwood of a total volume of 27.84 m^3, a mean diameter of 26.8 cm, a mean length of 3.6 m, and a mean volume of 0.208 m^3. The first cutter processed 281 pieces of long stackwood of a total volume of 27.82 m^3, a mean diameter of 15.2 cm, a mean length of 5 m, and a mean volume of 0.099 m^3. The second cutter processed 371 pieces of long stackwood of a total volume of 48.75 m^3, a mean diameter of 17.6 cm, a mean length of 5.2 m and a mean volume of 0.131 m^3. The first cutter processed a total of 79.08 m^3, and the second one a total of 76.59 m^3.

PROCESSED WOOD DURING THE SIMULTANEOUS CUTTING AND PROCESSING OF TREES – KUTJEVO WORK SITE
IZRAĐENO DRVO PRI ISTOVREMENOJ SJEČI I IZRADBI STABALA – RADILIŠTE KUTJEVO

Table 6 shows data on the processed wood on the Kutjevo work site during the simultaneous felling and processing of trees. The first cutter, working alongside a Torpedo tractor, cut and processed 280 trees of a total volume of 81.79 m^3, a mean breast-height diameter of 20.2 cm, a mean height of 14.9 m and a mean volume of 0.292 m^3. The second cutter cut and processed 289 trees, 109 trees more than the first one, of a total volume of 116.99 m^3, a mean breast-height diameter of 21.1 cm, a mean height of 15.4 m and a mean volume of 0.301 m^3. The mean walking distance of the first cutter from tree to tree was 10.1 m, and of the second cutter, 10.5 m.

The second cutter processed 12 pieces of commercial roundwood more than the first. The mean values differ marginally. When processing long stackwood, the second cutter processed 97 pieces more than the first, or 22.53 m^3. The second cutter processed 27.02 m^3 of the total processed wood, which was 30.5% more than the first cutter.

PROCESSED WOOD AT THE PLETERNICA WORK SITE
IZRAĐENO DRVO NA RADILIŠTU PLETERNICA

At the Pleternica work site (Table 7), one cutter both cut and processed the trees. He cut a total of 437 trees, of a total volume of 187.16 m^3. The mean breast-height diameter was 26.2 cm, the mean height was 23 m, and the mean volume of a tree was 0.428 m^3. The distance from tree to tree was 15.5 m. The total amount of commercial roundwood which was processed amounted to 389 pieces of a total volume of 60.47 m^3, a mean diameter of 19.6 cm, a mean length of 3.6 m, and a mean volume of 0.155 m^3.

Table 6. Data on trees which were cut and processed by cutters working alongside Torpedo and Ecotrac tractors on the Kutjevo work site

Tablica 6. Podaci o stablima koja su posjekli i izradili sjekači uz traktore Torpedo i Ecotrac na radilištu Kutjevo

Processed timber components *Sastavnice izrađenog drva*	Cutter with Torpedo tractor *Sjekač uz traktor Torpedo* * - x - **	Cutter with Ecotrac tractor *Sjekač uz traktor Ecotac* * - x - **
Number of cut trees, pieces *Broj posječenih stabala, kom*	280	389
Volume of cut trees, m^3 *Obujam posječenih stabala, m^3*	81.79	116.99
Diameter at breast height, cm *Prsni promjer, cm*	(10 - 20.2 - 55)	(9 - 21.1 - 45)
Tree height, m *Visina stabla, m*	(8 - 14.9 - 20)	(7 - 15.4 - 20)
Tree volume, m^3 *Obujam stabla, m^3*	(0.030 - 0.292 - 1.827)	(0.026 - 0.301 - 1.554)
Height to the crown, m *Visina do krošnje, m*	(0.5 - 5.8 - 16)	(1 - 2.9 - 12)
Distance from tree to tree, m *Udaljenost od stabla do stabla, m*	(0.5 - 10.1 - 150)	(0.5 - 10.5 - 100)
	Technical roundwood / *Tehnička oblovina*	
Number of pieces *Broj komada*	111	123
Processed volume, m^3 *Izrađeni obujam, m^3*	20.98	25.47
Diameter, cm *Promjer, cm*	(16 - 25.1 - 53)	(16 - 27.2 - 45)
Length, m *Duljina, m*	(2.0 - 3.5 - 6.0)	(2.0 - 3.5 - 6.0)
Piece volume, m^3 *Obujam komada, m^3*	(0.061 - 0.189 - 0.882)	(0.005 - 0.210 - 0.636)
	Long stackwood / *Višemetarsko prostorno drvo*	
Number of pieces *Broj komada*	374	471
Processed volume, m^3 *Izrađeni obujam, m^3*	40.70	63.23
Diameter, cm *Promjer, cm*	(8 - 15.9 - 34)	(9 - 17.7 - 38)
Length, m *Duljina, m*	(2.0 - 5.0 - 16.0)	(2.0 - 5.2 - 12.0)
Piece volume, m^3 *Obujam komada, m^3*	(0.013 - 0.109 - 0.554)	(0.002 - 0.130 - 0.680)
Total volume, m^3 *Ukupan obujam, m^3*	61.68	88.70

* Minimal value x Total or mean value ** Maximal value

** Najmanja vrijednost x Ukupna ili srednja vrijednost ** Najveća vrijednost*

Table 7. Data on the felling and processing by one cutter at Pleternica
Tablica 7. Podaci o sječi i izradbi jednog sjekača u Pleternici

Processed timber components *Sastavnice izrađenog drva*	Values *Vrijednosti* * - x - **
Number of cut trees, pieces *Broj posječenih stabala, kom*	437
Volume of cut trees, m^3 *Obujam posječenih stabala, m^3*	187.16
Diameter at breast height, cm *Prsni promjer, cm*	10 - 26.2 - 43
Tree height, m *Visina stabla, m*	9 - 23.0 - 31
Tree volume, m^3 *Obujam stabla, m^3*	0.027 - 0.428 - 2.349
Distance from tree to tree, m *Udaljenost od stabla do stabla, m*	1 - 15.4 - 120
Technical roundwood *Tehnička oblovina*	
Number of pieces *Broj komada*	389
Processed volume, m^3 *Izrađeni obujam, m^3*	60.47
Diameter, cm *Promjer, cm*	12 - 19.6 - 58
Length, m *Duljina, m*	2 - 3.6 - 8
Piece volume, m^3 *Obujam komada, m^3*	0.048 - 0.155 - 1.162
Long stackwood *Višemetarsko prostorno drvo*	
Number of pieces *Broj komada*	940
Processed volume, m^3 *Izrađeni obujam, m^3*	95.13
Diameter, cm *Promjer, cm*	10 - 13.4 - 60
Length, m *Duljina, m*	2 - 4.6 - 7
Piece volume, m^3 *Obujam komada, m^3*	0.038 - 0.101 - 1.696
Total processed volume, m^3 *Ukupan izrađeni obujam, m^3*	155.60

* Minimal value   x Total or mean value   ** Maximal value
* *Najmanja vrijednost*   *x Ukupna ili srednja vrijednost*   ** *Najveća vrijednost*

Long stackwood amounting to 940 pieces were also processed, of a total volume of 95.13 m³, a mean diameter of 13.4 cm, a mean length of 4.6 m, and a mean volume per piece of 0.101 m³. The total volume of processed wood amounted to 115.60 m³.

SKIDDED WOOD AT THE KUTJEVO WORK SITE
PRIVUČENO DRVO NA RADILIŠTU KUTJEVO

Data on skidded wood are shown in Tables 8 and 9. A Torpedo TD 75A tractor skidded a total of 171.49 m³. The mean volume of the load of 143 cycles amounted to 1.20 m³. The Torpedo tractor mostly skidded processed wood assortments and in 137 cycles skidded an average of 8.3 pieces per cycle. The mean volume of a piece was 0.145 m³.

The Torpedo tractor skidded an average of 8 pieces per cycle. In the total number of skidded pieces, 14 boles of an average volume of 1.10 m³ were skidded in 6 cycles. The mean volume of the assortment was 0.145 m³, and that of a bole 0.470 m³ (Table 8).

Table 8. Overview of skidded wood by a Torpedo TD 75A tractor at Kutjevo
Tablica 8. Prikaz privučenog drva traktorom Torpedo TD 75A u Kutjevu

Components of skidded timber *Sastavnice privučenog drva*	Total Ukupno	Stem Deblo	Timber assortments Drvni sortimenti
	* - x - **	* - x - **	* - x - **
Total skidded timber, m³ *Ukupno privučeno drvo, m³*	171.49	6.57	164.92
Total number of pieces *Ukupan broj komada*	1150	14	1136
Total length of pieces, m *Ukupna duljina komada, m*	6 765.2	279.6	6 485.6
Total cycle number *Ukupan broj turnusa*	143	6	137
Mean load volume, m³ *Srednji obujam tovara, m³*	0.53 - 1.20 - 1.89	0.60 - 1.10 - 1.52	0.53 - 1.20 - 1.89
Average number of pieces in a load *Prosječni broj komada u tovaru*	8.0	1 - 2.3 - 3	5 - 8.3 - 14
Mean piece length, m *Srednja duljina komada, m*	5.9	10.4 - 20.0 - 30	2 - 5.7 - 18
Mean piece volume, m³ *Srednji obujam komada, m³*	0.149	0.265 - 0.470 - 1.050	0.031 - 0.145 0.669
Mean piece diameter, cm *Srednji promjer komada, cm*	18.0	12 - 17.3 - 29	10 - 18.0 - 43

* Minimal value x Total or mean value ** Maximal value
* *Najmanja vrijednost* x *Ukupna ili srednja vrijednost* ** *Najveća vrijednost*

Table 9. An overview of skidded wood by the Ecotrac V 1033F tractor at Kutjevo
Tablica 9. Prikaz privučenog drva traktorom Ecotrac V 1033F u Kutjevu

Components of skidded timber *Sastavnice privučenog drva*	Total *Ukupno*	Stem *Deblo*	Timber assortments *Drvni sortimenti*
	* - x - **	* - x - **	* - x - **
Total skidded timber, m^3 *Ukupno privučeno drvo, m^3*	149.70	3.99	145.71
Total number of pieces *Ukupan broj komada*	991	5	986
Total length of pieces, m *Ukupna duljina komada, m*	5 764.5	112.3	5 652.2
Total cycle number *Ukupan broj turnusa*	134	3	131
Mean load volume, m^3 *Srednji obujam tovara, m^3*	0.54 - 1.12 - 2.41	1.09 - 1.33 - 1.62)	0.54 - 1.11 - 2.41
Average number of pieces in a load *Prosječni broj komada u tovaru*	7.4	1 - 1.7 - 3	3 - 7.5 - 13
Mean piece length, m *Srednja duljina komada, m*	5.8	13.4 - 22.5 - 30.9	2 - 5.7 - 18
Mean piece volume, m^3 *Srednji obujam komada, m^3*	0.151	0.338 - 0.798 - 1.283	0.031- 0.148 - 0.739
Mean piece diameter, cm *Srednji promjer komada, cm*	18.2	14 - 21.0 - 30	10 - 18.1 - 47

* Minimal value x Total or mean value ** Maximal value
* *Najmanja vrijednost x Ukupna ili srednja vrijednost ** Najveća vrijednost*

The Ecotrac tractor skidded a total of 149 m^3 of wood, of a mean volume per piece of 0.151 m^3 in 134 cycles. The mean volume of a load of wood assortments amounted to 1.12 m^3, and at skidding, 1.33 m^3. A load contained an average of 7.4 pieces (Table 9).

For similar working conditions and for the longwood processing method, Štefančić (1989) gives an average volume of 1.58 m^3 for an IMT 560 tractor load, and for the assortment processing method, an average volume of 1.38 m^3. In lowland conditions, for an IMT 558 tractor, Krpan (1984) gives average loads of 1.08 m^3, 1.09 m^3 and 0.98 m^3 volume, and Bojanin (1975) for the same tractor, mentions a mean volume per load of 1.35 m^3.

SKIDDED WOOD AT THE PLETERNICA WORK SITE
PRIVUČENO DRVO NA RADILIŠTU PLETERNICA

At the Pleternica work site, a Torpedo TD 75A tractor skidded 88.59 m^3 of wood in 56 cycles. The mean volume per load was 1.58 m^3 with an average of 11.1 pieces per load. An Ecotrac V-11-1033F tractor skidded 55.31 m^3 of wood in 47 cycles, of an average volume of 1.18 m^3 per load and an average of 8.6 pieces per load (Table 10).

Table 10. Overview of skidded wood at the Pleternica work site
Tablica 10. Prikaz privučenog drva na radilištu Pleternica

Components of skidded timber *Sastavnice privučenog drva*	Torpedo * - x - **	Ecotrac * - x - **
Total skidded timber volume, m^3 *Ukupno privučeni drv.obujam, m^3*	88.59	55.31
Total number of pieces *Ukupan broj komada*	623	403
Total length of pieces, m *Ukupna duljina komada, m*	3 271	2 084.6
Total cycle number *Ukupan broj turnusa*	56	47
Mean load volume, m^3 *Srednji obujam tovara, m^3*	0.919 - 1.58 - 2.206	0.726 - 1.18 - 1.775
Average number of pieces in a load *Prosječni broj komada u tovaru*	7 - 11.1 - 14	5 - 8.6 - 13
Mean piece length, m *Srednja duljina komada, m*	2 - 5.2 - 7.2	2 - 5.2 - 7
Mean piece volume, m^3 *Srednji obujam komada, m^3*	0.038 - 0.142 - 0.676	0.038 - 0.14 - 0.513
Mean piece diameter, cm *Srednji promjer komada, cm*	10 -18.6 - 47	10 - 18.4 - 35

* Minimal value x Total or mean value ** Maximal value
* *Najmanja vrijednost* x *Ukupna ili srednja vrijednost* ** *Najveća vrijednost*

Figure 3. Overview of the volume of a load according to wood assortments
Slika 3. Prikaz obujma tovara po drvnim sortimentima

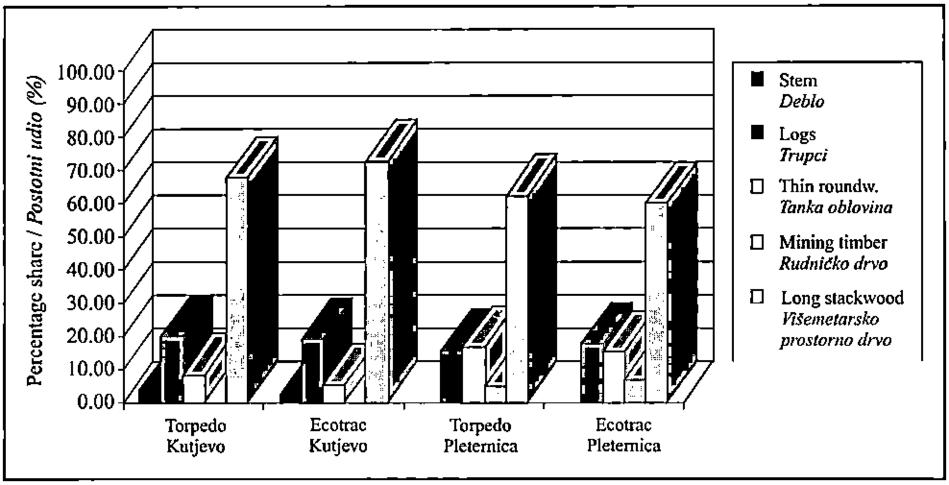


Figure 3 shows the volume of a load according to wood assortments. It is evident from this overview that the largest part consisted of long stackwood, followed by logs and thin roundwood.

TIME ANALYSIS
ANALIZA VREMENA

TOTAL TIME CONSUMPTION OF FELLING
UKUPNO UTROŠENA VREMENA PRETHODNE SJEČE

The cutting of tees in the departments 55a and 56a of the *agricultural* unit management Krndija I, on the Kutjevo work site, was monitored over five working

Table 11. Effective tree-cutting time and average time consumption per tree at Kutjevo
Tablica 11. Efektivno vrijeme sječe stabala i prosječan utrošak vremena po stablu u Kutjevu

Working operation *Radni zahvat*		Total time consumption *Ukupno utrošeno vrijeme*			Time per tree *Vrijeme po stablu*
		min	%		min
Tree time *Stablovno vrijeme*	1. Walking to the tree *1. Hod do stabla*	1 025.53	18.11	39.82	0.34
	2. Determining felling direction *2. Određivanje smjera rušenja*	24.83	0.44	0.96	0.01
	3. Cleaning the surroundings *3. Čišćenje okoliša*	19.37	0.34	0.75	0.01
	4. Processing stem base *4. Obrada žilišta*	0.10	0.00	0.00	0.00
	5. Making the undercut *5. Izrada zasjeka*	102.11	1.80	3.96	0.03
	6. Laying in *6. Potpiljivanje*	118.25	2.09	4.59	0.04
	7. Wedging *7. Zabijanje klinova*	0.54	0.01	0.02	0.00
	8. Tree falling *8. Padanje stabla s oslobađanjem*	1 272.21	22.49	49.40	0.42
	9. Beard cutting *9. Obrada brade*	12.68	0.22	0.49	0.00
Effective time *Efektivno vrijeme*		2 575.62	45.49	100.00	0.85
Delay times *Opća vremena*		3 085.99	54.51		1.01
Total time *Ukupno vrijeme*		5 661.61	100.00		1.86

days. Four cutters worked in a team. Three members permanently carried out the tasks of cutting and processing, while the fourth worked as a cutter or tractor driver, according to the need. In all, 3,047 trees were cut of a total volume of 987.85 m^3. The measuring task took a total of 5,661.61 minutes (Table 11).

In the distribution of total time consumption, the share of effective time was 45.49%, against 54.51% of delay time. The largest part of total time consisted of the working operation of clean felling – 22.49%, and next walking to the tree at an average distance of 9.2 m – 18.11%. In the distribution of effective time, clean felling took up 49.40% of the time, and walking to the tree amounted to 39.82% of the time. The total time per tree amounted to 1.86 minutes, and the effective time amounted to 0.85 minutes. To walk from tree to tree, an average of 0.34 minutes was spent, and 0.42 minutes was taken in felling. Tomanić et al. (1978) suggest the following formula to calculate the time of transfer to the tree:

$t = -0.05 + 0.02968\ Lp + 0.01143\ G$, where

t = time of transfer, Lp = average length of transfer, G = inclination of the terrain on the felling area as a percentage.

For the observed conditions, with a terrain inclination of 12% and an average transfer length of 9.2 m, the time according to the formula of Tomanić et al. (1978) was 0.36 minutes, which, in relation to the measured time of transfer from tree to tree, makes up a difference of 0.02 minutes.

ALLOWANCE CUTTING TIME
DODATNO VRIJEME SJEČE

Allowance cutting time includes time for the lunch break, rest, justified interruptions, interruptions for sporadic jobs, technical interruptions and preparation/completion time.

Allowance time amounted to 1,046.47 minutes, or 40.61% of effective time, that is, 0.34 min/tree, or 1.05 min/m^3. Allowance time was allowance to effective time by using the allowance time coefficient (Kd) which is calculated according to the formula:

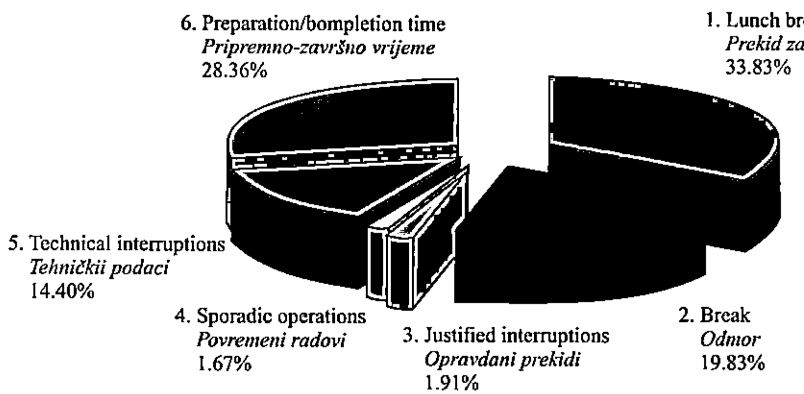
$$Kd = 1 + pd / 100,$$

where pd = allowance time percentage.

Another way is to add the absolute amount of allowance time to effective time. In the structure of allowance time, the largest share was taken up by the lunch break at 33.83%, then by preparation/completion time at 28.36%, and the smallest share was taken up by sporadic operations at 1.67% and by justified interruptions at 1.91%. It was calculated that the lunch break should take 30 minutes for 8 hours of work.

Breaks during work enable the worker to maintain the normal intensity of work and to prevent exhaustion to a certain degree. Interruptions for breaks and respite took place eight times a day at the most. The shortest respite was 0.30 minutes. Breaks of up to 5 minutes were allowed. It was assessed that longer breaks were not necessary to restore energy, due to the relatively small share that work with a power saw had in effective time. Most energy was consumed in walking to the tree and on freeing the tree. Justified interruptions, sporadic work and technical interruptions were recognised in all the consumed times. The preparation/completion time was recognised, according to the evaluation of the time necessary to prepare the tools and equipment, at up to 15 minutes at the beginning of the working day, and at 5 minutes at the end of the day.

Figure 4. Distribution of allowance time in felling tree at Kutjevo
Slika 4. Raspodjela dodatnoga vremena na sječi stabala u Kutjevu



EFFECTIVE AND DELAY TIMES OF PROCESSING, AND OF CUTTING AND PROCESSING TREES AT KUTJEVO
EFEKTIVNO I OPĆA VREMENA IZRADBE TE SJEČE I IZRADBE STABALA U KUTJEVU

The work of cutters working alongside the Torpedo (first cutter) and Ecotrac (second cutter) tractors on the processing of previously felled trees, as well as on the cutting and processing of standing trees, was monitored over 15 working days. Data on the felling and processing of standing trees are shown in Table 6. The work of the first cutter was measured at 5,309.67 minutes, and of the second one at 5,324.70 minutes. During the first 5 days of measuring, the cutters cut and processed the remaining standing trees, and during the next 10 days they processed previously felled, or felled and processed trees. In the total time consumed, the effective time of the first cutter amounted to 35.95%, while the delay time came to 64.05%. The effective time of the second cutter amounted to 42.93%, while the delay time amounted to 57.07%. Vondra (1989) mentions that when processing roundwood of different lengths and long commercial timber, delay time amounts to 77.9% of net working time. In Table 12 it can be seen that the total time of the first cutter in processing amounted to 531.44 minutes, or 2.35 minutes per tree. The second cutter spent 478.38 minutes, or 2.08 minutes per tree. The effective cutting and processing time of the first cutter amounted to 632.84 minutes, or 2.26 minutes per tree, and of the second cutter, 818.22 minutes, or 2.10 minutes per tree. The effective time of the first cutter in processing trees was 0.09 minutes,

Table 12. Time structure at processing, cutting and processing, percentage of time according to total and effective time and time consumption per tree at Kutjevo
Tablica 12. Struktura vremena na izradbi, sječi i izradbi, postotni udio vremena prema ukupnom i efektivnom vremenu i utrošak vremena po stablu u Kutjevu

Type of operation or procedure *Vrsta operacije ili zahvata*	Time consumption *Utrošak vremena*							
	Cutter with Torpedo (1) *Sjekač uz Torpedo (1)*				Cutter with Ecotrac (2) *Sjekač uz Ecotrac (2)*			
	min	%		min/tree *min/stablu*	min	%		min/tree *min/stablu*
1. Processing time *1. Vrijeme izradbe*	531.44	10.01	27.84	2.35	478.38	8.98	20.93	2.08
1.1. Tree time *1.1 Stablovno vrijeme*	365.26	6.88	19.13	1.62	362.29	6.80	15.85	1.58
1.2. Assortment time *1.2 Sortimentno vrijeme*	166.18	3.13	8.70	0.74	116.09	2.18	5.08	0.50
2. Cutting and processing time *2. Vrijeme sječe i izradbe*	632.84	11.92	33.15	2.26	818.22	15.37	35.80	2.10
2.1. Tree time *2.1 Stablovno vrijeme*	500.23	9.42	26.20	1.79	668.30	12.55	29.24	1.72
2.2. Assortment time *2.2 Sortimentno vrijeme*	132.61	2.50	6.95	0.47	149.92	2.82	6.56	0.39
3. Load preparation *3. Rad na pripremi tovara*	681.89	12.84	35.72	1.35	986.71	18.53	43.17	1.59
4. Auxiliary landing work *4. Rad na pomoćnom stovarištu*	62.90	1.18	3.29	0.12	2.39	0.04	0.10	0.00
5. Effective time *5. Efektivno vrijeme*	1909.07	35.95	100.00	3.77	2285.70	42.93	100.00	3.69
6. Delay time *6. Opća vremena*	3400.60	64.05		6.72	3039.00	57.07		4.91
7. Total time *7. Ukupno vrijeme*	5309.67	100.00		10.49	5324.70	100.00		8.60

or 3.8% per tree longer than in cutting and processing. The second cutter spent 0.02 minutes less of effective time in processing, or 1% less in comparison with the net time in cutting and processing.

To prepare the load, the first cutter spent 681.89 minutes, or 1.35 minutes per tree, that is, 35.72% of effective time, and the second 986.71 minutes, or 1.59 minutes per tree, that is, 43.17% of effective time. Martinić (1990) notes that the time the cutters spend on tractor skidding activities in one day amounts to 88 min/day in one variation, and 95 min/day in the second variation. In these time structures, load fastening takes up 60%, and the manual bunching of the load 39%. At the end of the working day, the cutters sometimes helped with the inspection of the last tractor loads at the auxiliary landing.

The effective time per tree of the first cutter amounted to 3.77 minutes, and of the second one, 3.69 minutes. The time spent by the first cutter on the cutting and processing of 140.76 m^3 of timber amounted to 13.56 min/m^3 of effective time, 24.16 min/m^3 of delay time or to a total of 37.72 min/m^3. In cutting and processing 165.39 m^3 of timber, the second cutter spent 13.82 min/m^3 of effective time, 18.38 min/m^3 of delay time, or a total of 32.21 min/m^3. In similar conditions of teamwork and by using the longwood method, Štefančić (1989) gives a consumption of time of 39.70 min/m^3, of which effective time amounts to 13.33 min/m^3, or only 33.58% of total time. If the assortment method of cutting and processing is used, the same author mentions that the time consumed amounts to 29.36 min/m^3, of which the effective time is 17.96 min/m^3, or 61.17%. The consumption of effective time for teamwork in cutting and processing an average tree of a DBH of 31.3 cm (Tomičić) amounts to 6.69 minutes, and for binding the load, 1.39 minutes. If the assortment method is used and with one worker, the same author gives an effective time consumption of 9.94 minutes per tree with a mean DBH of 21 cm. In a thinned stand of common oak and alder (Bojanin et al., 1989), the effective cutting and processing time of a tree of a DBH of 20 cm amounts to 6.20 minutes for an oak, and 5.23 minutes for an alder.

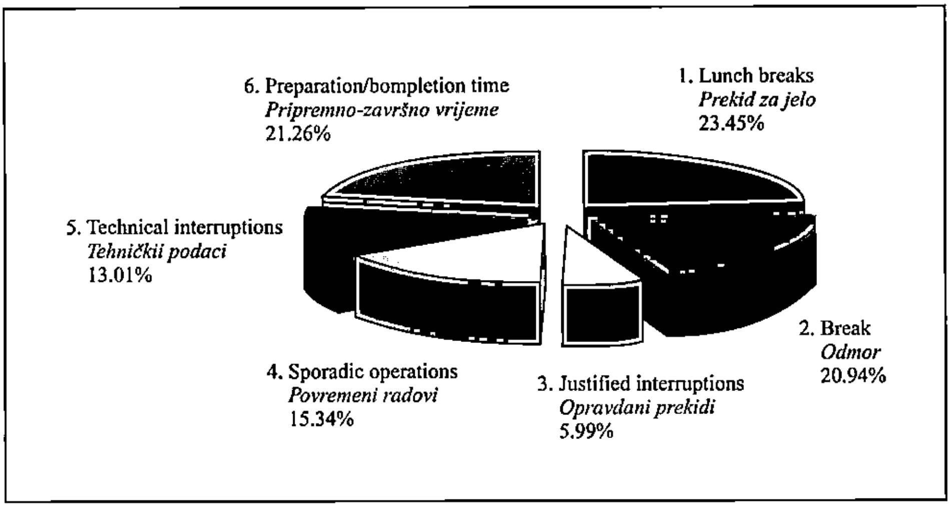
Delay time in comparison with net cutting and processing time in Sweden amounts to 45%, and in Austria to 56%. In Germany, from 61% of delay time, as much as 80% is taken for the workers' rest, and 20% for all the other interruptions (Martinić, 1990).

ALLOWANCE PROCESSING TIME, AND CUTTING AND PROCESSING TIME AT KUTJEVO
DODATNO VRIJEME IZRADBE TE SJEČE I IZRADBE U KUTJEVU

Allowance processing time, and the cutting and processing time of the first cutter amounted to 1,407.48 minutes, or 73.7% of effective time. The allowance time of the second cutter amounted to 1,377.50 minutes, or 60.3% of effective time. When calculating allowance time, half an hour lunch break was accepted for 8 hours of work. All the breaks were accepted up to 5 minutes at the most, and justified interruptions in the total amount as they occurred. The sporadic jobs of the first cutter made up 15.34% of allowance time, and for the second cutter, 6.64%. Technical interruptions amounted to 13.01% and 12.68% respectively, and the largest part of this time was spent in replenishing with fuel. The preparation/completion time made up 21.26% and 27.42 % of allowance time respectively. In 15 days of work, the formed preparation/completion time of the first cutter amounted to 299.30 minutes, and that of the second cutter came to 377.73 minutes, that is, 19.95 min/day and 25.18 min/day respectively. For a hilly terrain, Bojanin et al. (1994) established allowance time as 51% of net working time. This also comprised a 30-minute lunch break. The same authors state that without the lunch break, allowance time amounts to 41.5%. Backhaus (1990) reports that with cutting and processing quotas, allowance time in the whole of Germany amounts to an average of 40%.

The allowance time of the first cutter amounted to 7.56 min/m^3 of processed wood assortment of felled trees and of cut and processed standing trees. The allowance time of the second cutter amounted to 5.56 min/m^3. The distribution of allowance time is shown in Figures 5 and 6.

Figure 5. The allowance processing time, and cutting and processing time of cutters working alongside a Torpedo tractor at Kutjevo
Slika 5. Dodatno vrijeme izradbe te sječe i izradbe sjekača uz traktor Torpedo u Kutjevu

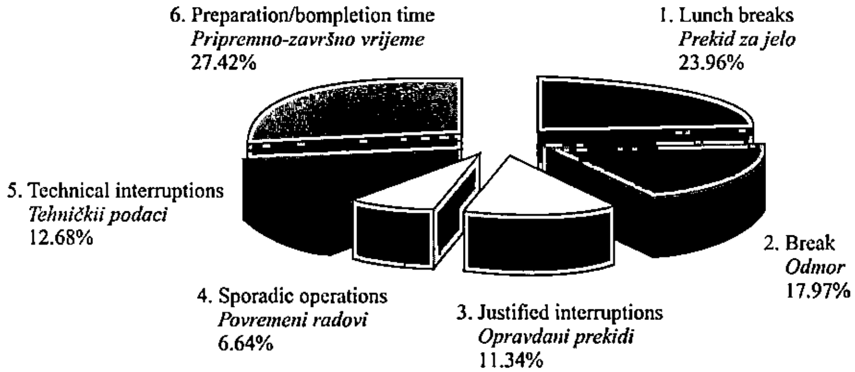


EFFECTIVE AND DELAY TIME OF WOOD ASSORTMENT INSPECTION AT KUTJEVO
EFEKTIVNO I OPĆA VREMENA PREUZIMANJA DRVNIH SORTIMENATA U KUTJEVU

A total of 4,521.55 minutes was spent on the inspection of wood assortments (Table 13). According to the data on wood volume shown in Table 15, the effecti-

Figure 6. The allowance processing time, and cutting and processing time of cutters wor king alongside an Ecotrac tractor at Kutjevo

Slika 6. Dodatno vrijeme izradbe te sječe i izradbe sjekača uz traktor Ecotrac u Kutjevu



ve time for 2,038 pieces, or 273.19 m³ of inspected wood assortments, amounted to an average of 6.21 min/m³, the delay time to 13.13 min/m³ and the total time to an average of 19.33 min/m³. Štefančić (1989) states that the consumption of net time for inspection amounts to 6.27 min/m³, and of total time to 19.26 min/m³, of which 8.93 min/m³ is spent on unnecessary interruptions to organise residue. In the second case, the cutter in a team at the auxiliary landing works an effective 134 minutes, or 27.9% of the total time (Martinić, 1990).

In the total time spent on inspection, effective time amounted to 20.69%, and delay time to 79.31%. In effective time, most time was spent on measuring commercial roundwood (27.35%), then to cover the distance from load to load at the auxiliary landing (25.18%). A total of 22.15% of time was spent on measuring stackwood, and the least net time was spent on bucking wood assortments (3.66%).

Table 13 also shows the time consumption of inspection per piece and per m³. Effective time per piece of wood assortment (2,038 pieces) amounted to 0.99 minutes, and total inspection time to 2.75 min.

ALLOWANCE TIME AT INSPECTION OF WOOD ASSORTMENTS AT KUTJEVO
DODATNO VRIJEME PRI PREUZIMANJU DRVNIH SORTIMENATA U KUTJEVU

Allowance time amounted to 630.18 minutes, or 67.35% of effective time. Such a high percentage was the consequence of the small consumption of effective time, and since interruptions are necessary during work regardless of how busy the worker is.

Table 13. Time consumption of the inspection of wood assortments at the auxiliary landing

Tablica 13. Utrošak vremena pri preuzimanju drvnih sortimenata na pomoćnom stvarištu

Type of operation or activity *Vrsta operacije ili zahvata*	Total time *Ukupno vrijeme*	Time share *Udio vremena*			
		per total time *prema ukupnom vremenu*	per effective time *prema efektivnom vremenu*	per timber assortment *po drvnom sortimentu*	per m^3 *po m^3*
	min	%		min	
1. Walking to the load *1. Hod do tovara*	235.58	5.21	25.18	0.12	0.86
2. Bucking timber assortments *2. Prikrajanje drvnih. sortimenata*	34.24	0.76	3.66	0.02	0.13
3. Cross-cutting and finalisation *3. Trupljenje i dorada*	93.11	2.06	9.95	0.05	0.34
4. Measuring technical roundwood *4. Mjerenje tehničke oblovine*	255.93	5.66	27.35	0.53	2.86
5. Setting plastic boards *5. Zakucavanje pločica*	51.55	1.14	5.51	0.11	0.58
6. Measuring stackwood *6. Mjerenje prostornog drva*	207.29	4.58	22.15	0.13	1.13
7. Marking with numbering hammer *7. Označavanje kolobrojem*	58.01	1.28	6.20	0.04	0.32
Effective time *Efektivno vrijeme*	935.71	20.69	100.00	0.99	6.21
Delay times *Opća vremena*	3 585.84	79.31		1.76	13.13
Total time *Ukupno vrijeme*	4 521.55	100.00		2.75	19.33

When establishing allowance time, the lunch break was determined according to the working day, so that 30 minutes were allocated for 8 hours of work. Figure 7 shows the share of allowance time. The largest share, 44.84%, was taken by the lunch break, then by preparation/completion time – 26.01%. Justified interruptions amounted to 12.69%, and sporadic operations came to 11.45%.

CUTTING AND PROCESSING TIME AT PLETERNICA
VREMENA SJEČE I IZRADBE U PLETERNICI

One cutter worked on both cutting and processing. Over 9 days, he spent a total of 3,810.15 minutes (Table 14). Effective time amounted to 1,582.44 minutes, or 41.53%, and delay time to 2,227.71 minutes, or 58.47%. The share of cutting and processing time in total time amounted to 40.05% and to 96.42% of effective

Figure 7. Allowance time in the inspection of wood assortments at the auxiliary landing at Kutjevo
Slika 7. Dodatno vrijeme preuzimanja drvnih sortimenata na pomoćnom stovarištu u Kutjevu

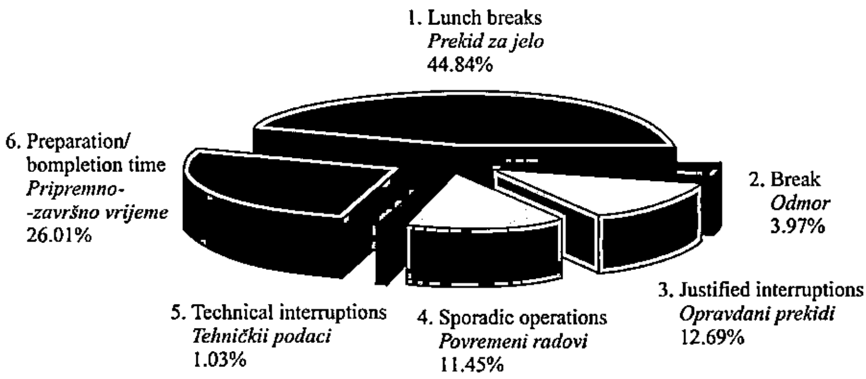


Table 14. Effective and delay tree cutting and processing times and time consumption per tree at Pleternica
Tablica 14. Efektivno i opća vremena sječe i izradbe stabala te utrošak vremena po stablu u Pleternici

Type of operation or procedure *Vrsta operacijeili zahvata*	Time consumption *Utrošak vremena*	Share per *Udio prema*		Shareper tree *Udio po stablu*
		total time *ukupnom vremenu*	effective time *efektivnom vremenu*	
	min	%		min
1. Felling and processing time *1. Vrijeme sječe i izradbe*	1 525.78	40.05	96.42	3.49
1.1 Tree time *1.1 Stablovno vrijeme*	1 203.50	31.59	76.05	2.75
1.2 Assortment time *1.2 Sortimentno vrijeme*	322.28	8.46	20.37	0.74
2. Load preparation *2. Priprema tovara*	56.66	1.49	3.58	0.13
3. Effective time *3. Efektivno vrijeme*	1 582.44	41.53	100.00	3.62
4. Delay times *4. Opća vremena*	2 227.71	58.47		5.10
5. Total time *5. Ukupno vrijeme*	3 810.15	100.00		8.72

time. In total time, tree time amounted to 31.59%, or 7.73 min/m^3, and assortment time was 8.46%, or 2.07 min/m^3. In effective time, tree time amounted to 76.05% of the time, and assortment time came to 20.37%. In cutting and processing beech in a mountainous area, Bojanin and Krpan (1994) give a consumption of 8.3 min/m^3 of assortment time for a mean DBH of 19 cm, and a consumption of 10.5 min/m^3 for a DBH of 22 cm.

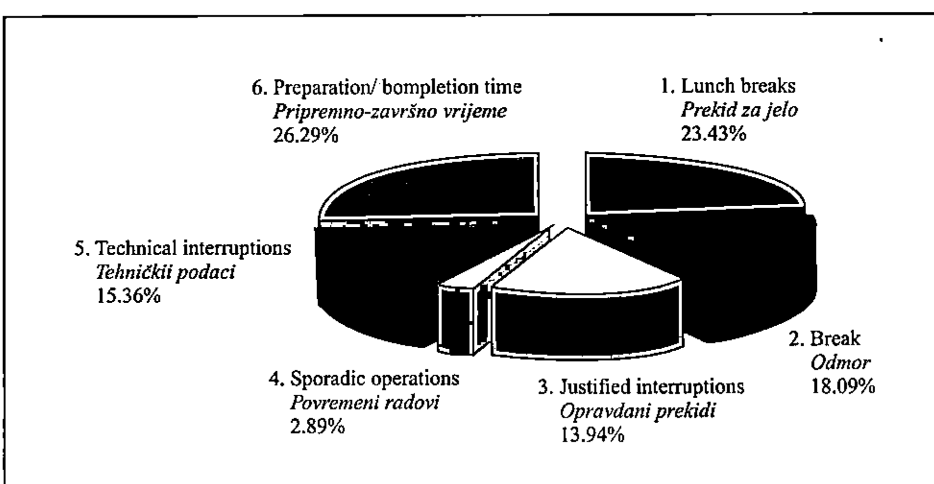
The cutter sometimes bound the load and spent a total of 56.66 minutes in doing so, which amounted to 1.49% of total time, and 3.58% of effective time. The processed volume of wood assortments from 437 cut trees amounted to 155.60 m^3. Total time per tree amounted to 8.72 minutes, and for processed wood assortments to 24.49 min/m^3. Effective time per tree amounted to 3.62 minutes, or 10.17 min/m^3. For similar conditions of teamwork, the total cutting and processing time of wood assortments amounts to 29.36 min/m^3, and net time to 17.96 min/m^3 (Štefančić, 1989).

ALLOWANCE TIME IN CUTTING AND PROCESSING AT PLETERNICA
DODATNO VRIJEME PRI SJEČI I IZRADBI U PLETERNICI

Allowance cutting and processing time shown in Figure 8 amounted to 1,016.41 minutes, or to 64.23% of effective time.

The largest share was taken by preparation/completion time – 267.18 minutes, or 26.29% of effective time. A considerable amount of time was spent on travelling to the felling site and back, because the cutter had to walk and not ride in the

Figure 8. Distribution of allowance time of cutting and processing at Pleternica
Slika 8. Raspodjela dodatnog vremena sječe i izradbe u Pleternici



tractor. The lunch break took 238.13 minutes, or 23.43%. Breaks were frequent due to the high temperatures and high humidity during the day, and lasted on average 20.46 minutes per day. The workers had to consult on the organisation of the work quite frequently, because all the workers worked on a relatively small area, in a line one behind the other. Sporadic operations had a share of only 2.89%. Technical interruptions occurred when there was a real need to replenish fuel or sharpen the chain, and lasted 156.14 minutes, or 15.36% of this time.

TIMES OF INSPECTION OF WOOD ASSORTMENTS AT THE PLETERNICA FELLING SITE
VREMENA PREUZIMANJA ŠUMSKIH SORTIMENATA NA SJEČINI U PLETERNICI

The consumption of effective and delay time is shown in Table 15. Effective time amounted to 815.45 minutes, or 21.40%, and delay time to 2,995.58 minutes, or 78.61%. A total of 153.08 m³ was inspected, of which 329 pieces of com-

Table 15. Time consumption on the inspection of wood assortments at the Pleternica felling site
*Tablica 15. Utrošci vremena pri preuzimanju drvnih sortimenata u sječini u Pleter*nici

Type of operation or procedure *Vrsta operacija ili zahvata*	Total time *Ukupno vrijeme*	Time share *Utrošak vremena*			
		per total time *prema ukupnom vremenu*	per effective time *prema efektivnom vremenu*	per timber assortment *po drvnom sortimentu*	per m³ *po m³*
	min	%		min	
1. Walking to the stem *1. Hod do debla*	158.45	4.16	19.43	0.14	1.00
2. Measuring *2. Mjerenje*	638.79	16.76	78.34	0.58	4.04
3. Setting plastic boards *3. Zakucavanje pločica*	5.68	0.15	0.70	0.01	0.04
4. Marking with numbering hammer *4. Označavanje kolobrojem*	12.53	0.33	1.54	0.01	0.08
Effective time *Efektivno vrijeme*	815.45	21.40	10.00	0.74	5.16
Delay times *Opća vremena*	2 995.58	78.60		2.73	18.95
Total time *Ukupno vrijeme*	3 811.03	100.00		3.47	24.11

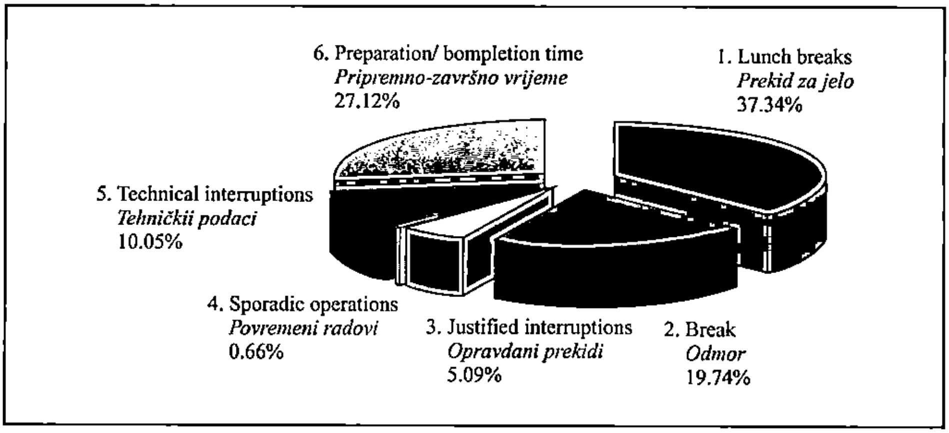
mercial roundwood of a mean volume of 0.181 m³ and 768 pieces of long stackwood of a mean volume of 0.122 m³. The time spent on measuring wood assortments in relation to effective time amounted to 78.34%, or 0.58 minutes per piece, that is, 4.04 min/m³. Effective time amounted to 5.16 min/m³, and delay time 18.95 min/m³, which made up a total of 24.11 min/m³. In similar working conditions, it was noted that a total of 5.58 min/m³ is spent on inspecting wood assortments in the forest, including 3.13 min/m³, or 56.14%, of effective time, and 2.45 min/m³ of delay time (Štefančić, 1989).

ALLOWANCE TIME OF THE INSPECTION OF WOOD ASSORTMENTS AT THE PLETERNICA FELLING SITE
DODATNO VRIJEME PREUZIMANJA DRVNIH SORTIMENATA U SJEČINI U PLETERNICI

Allowance time amounted to 637.97 minutes, or 78.23 % of the effective time, that is, 70.88 min/day. The lunch break was determined according to the total time consumption per day, and amounted to 37.34% of allowance time, that is, to 6.25% of total working time consumption.

Breaks of up to 5 minutes at the most were acknowledged, and were taken 2 to 5 times during the working day. They amounted to a total of 125.96 minutes, or 19.74%, that is, an average of 14 minutes per day. Justified breaks were included in the total amount of 32.49 minutes, or 5.09%. Technical interruptions amounted to a total of 64.14 minutes, or 10.05%. Preparation/completion times lasted 172.99 minutes, or 27.12%. Preparation time and time for collecting the tools up to 15 minutes per day at the most were acknowledged, including 10 minutes on preparation time and 5 minutes on collecting the tools. The time spent on the journey to the felling site and back was included in the total amount (Figure 9).

Figure 9. Allowance time of inspection of wood assortments at the Pleternica felling site
Slika 9. Dodatno vrijeme preuzimanja drvnih sortimenata u sječini na radilištu Pleternica

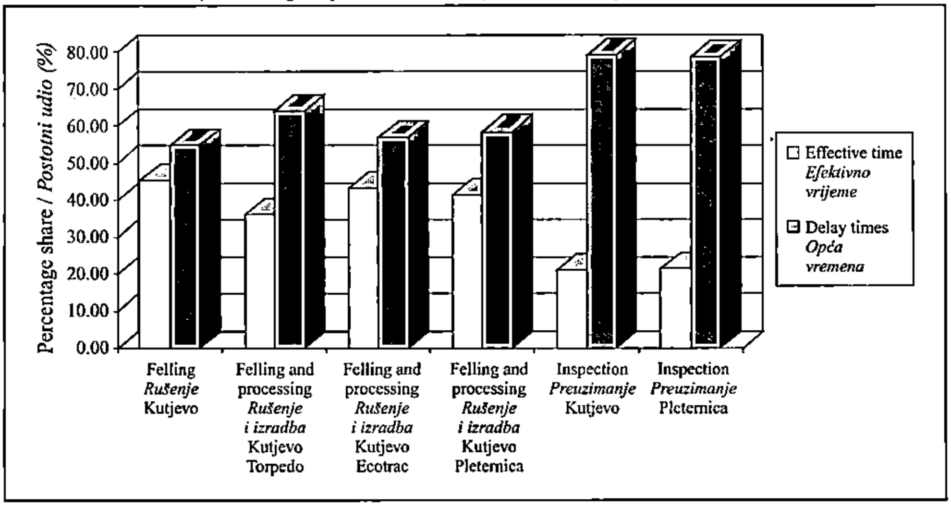


The amount of allowance time of 78.23% is too high. The reason for this lies in the fact that the share of effective time, that is, the organisation of work and the engagement of the cutters, is too small.

RELATIONSHIP BETWEEN THE EFFECTIVE AND DELAY TIME OF CUTTERS
ODNOS EFEKTIVNOG I OPĆIH VREMENA SJEKAČA

Figure 10 shows the relationship between effective and delay time in all the operations of the cutters. The largest effective and smallest delay time was achieved in cutting trees, and the smallest effective and largest delay time was taken in inspecting wood assortments.

Figure 10. The relationship between the effective and delay time of cutters in total time consumption
Slika 10. Odnos efektivnog i općih vremena sjekača u ukupno utrošenom vremenu



TOTAL TIME CONSUMPTION OF TRACTORS
UKUPNO UTROŠENA VREMENA TRAKTORA

TOTAL TIME CONSUMPTION OF A TORPEDO TD 75A TRACTOR
UKUPNO UTROŠENA VREMENA TRAKTORA TORPEDO TD 75A

Table 16 shows the total time consumption of a Torpedo tractor at both work sites and the relative share of individual time in total and effective time.

The work of the tractor was monitored at the Kutjevo work site in the course of 15 days, and at the Pleternica work site in the course of 9 days. At Kutjevo, 143

Table 16. Structure of total time consumption of a Torpedo TD 75A tractor
Tablica 16. Struktura ukupno utrošenih vremena traktora Torpedo TD 75A

Type of operation *Vrsta aktivnosti*	Time consumption *Utrošak vremena*					
	Torpedo - Kutjevo			Torpedo - Pleternica		
	Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema* total time *ukupnom vremenu*	Percentage per *Postotni udio prema* effective time *efektivnom vremenu*	Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema* total time *ukupnom vremenu*	Percentage per *Postotni udio prema* effective time *efektivnom vremenu*
	min	%		min	%	
1. Unloaded tractor travell *1. Vožnja neopterećenog traktora*	319.85	5.32	9.02	123.21	3.22	6.32
2. Loaded tractor travell *2. Vožnja opterećenog traktora*	384.72	6.40	10.85	175.96	4.60	9.03
3. Felling site work *3. Rad na sječini*	2 162	35.98	60.98	1 055.2	27.56	54.13
3.1. Taking up a position *3.1. Zauzimanje položaja*	152.32	2.53	4.30	71.27	1.86	3.66
3.2. Pulling out of rope *3.2. Izvlačenje užeta*	149.02	2.48	4.20	100.23	2.62	5.14
3.3. Binding load (tractor driver) *3.3. Vezanje tovara (traktorist)*	582.54	9.69	16.43	455.83	11.91	23.38
3.4. Skidding and lifting load *3.4. Privlačenje i podizanje tovara*	1.22	0.02	0.03	-	-	-
3.5. Fixing load *3.5. Ispravljanje tovara*	327.15	5.44	9.23	196.35	5.13	10.07
3.6. Winching *3.6. Privitlavanje*	190.5	3.17	5.37	165.83	4.33	8.51
3.7. Move up and down *3.7. Silaženje i penjanje*	77.36	1.29	2.18	35.76	0.93	1.83
3.8. Preparing and binding load *3.8 Priprema i vezanje tovara sjekača*	681.89	11.35	19.23	29.93	0.78	1.54
4. Auxiliary landing work *4. Rad na pomoćnom stovarištu*	678.74	11.30	19.14	595.01	15.54	30.52
4.1. Loaded tractor travell *4.1. Vožnja opterećenog traktora*	98.62	1.64	2.78	87	2.27	4.46

4.2 Winching *4.2. Privitlavanje*	2.29	0.04	0.06	-	-	-
4.3. Move up and down *4.3. Silaženje i penjanje*	69.16	1.15	1.95	28.49	0.74	1.46
4.4. Unfastening load *4.4. Odvezivanje tovara*	197.95	3.29	5.58	264.19	6.90	13.55
4.5. Unbinding rope *4.5. Izvlačenje užeta*	5.55	0.09	0.16	19.51	0.51	1.00
4.6. Making a wood stack *4.6. Uređenje složaja*	209.79	3.49	5.92	137.86	3.60	7.07
4.7. Unloaded tractor turning *4.7. Okretanje neopterećenog traktora*	20.61	0.34	0.58	1.77	0.05	0.09
4.8. Unloaded tractor travell *4.8. Vožnja neopterećenog traktora*	74.77	1.24	2.11	56.19	1.47	2.88
5. Effective time *5. Efektivno vrijeme*	3 545.31	59.00	100.00	1 949.38	50.91	100.00
6. Delay times *6. Opća vremena*	2 463.44	41.00	-	1 879.42	49.09	-
7. Total time *7. Ukupno vrijeme*	6 008.75	100.00	-	3 828.8	100.00	-
8. Total skidded timber volume, m^3 *8. Ukupno privučeni drvni obujam,* m^3	171.49	-	-	88.59	-	-
9. Effective time per unit, min/m^3 *9. Efektivno vrijeme po jedinici,* min/m^3	20.67	-	-	22.00	-	-
10. Total time per unit, min/m^3 *10. Ukupno vrijeme po jedinici,* min/m^3	35.04	-	-	43.22	-	-
11. Realised daily output, m^3/day *11. Ostvareni dnevni učinak,* m^3/dan	11.43	-	-	9.84	-	-

tractor cycles were measured, and at Pleternica 56 cycles were recorded, which makes a total of 199 tractor cycles. At the Kutjevo work site, 6,008.75 minutes were counted, and at the Pleternica work site, 3,828.80 minutes of work. The structure of total time consumption is shown in Table 36, while the structure of delay time is displayed in Table 37. Effective time was 8.09% longer at Kutjevo than at Pleternica. Delay time amounted to 41.0% and 49.09% respectively. Krpan (1984) holds that the average delay time of 40.0% is too high. Effective time per unit amounted to 20.67 minutes, or 22.0 minutes, which was 6.4% more than at Pleternica. The total time amounted to 35.04 min/m³, that is, 43.22 min/m³. At Pleternica, it was 23.3% higher than at Kutjevo. With an articulated wheeler tractor, Bojanin (1974) believes that effective time is satisfactory if it amounts to 79.7% of total time.

ALLOWANCE TIME OF THE TORPEDO TD 75A TRACTOR
DODATNO VRIJEME TRAKTORA TORPEDO TD 75A

Table 17 shows the structure of allowance time for a Torpedo TD 75A tractor. Allowance time is made up of parts of delay time which must be acknowledged, since they arise as no fault of the worker.

Allowance time is determined in order to calculate the time and efficiency quotas, and is allowance to effective time in the form of a percentage, an allowance time coefficient or an absolute amount.

Some authors, as shown by Krpan (1984), include justified and personal interruptions in allowance time, as well as breaks and preparation/completion time. If the half-hour lunch break is not included in allowance time (Bojanin 1971, Krivec, 1967), then the daily working time lasts 450 minutes.

According to Table 38, allowance time for a Torpedo TD 75A tractor at Kutjevo amounted to 837.63 minutes, or 23.6%, and at Pleternica to 510.11 minutes,

Table 17. Structure of allowance time of a Torpedo TD 75A tractor
Tablica 17. Struktura dodatnog vremena traktora Torpedo TD 75A

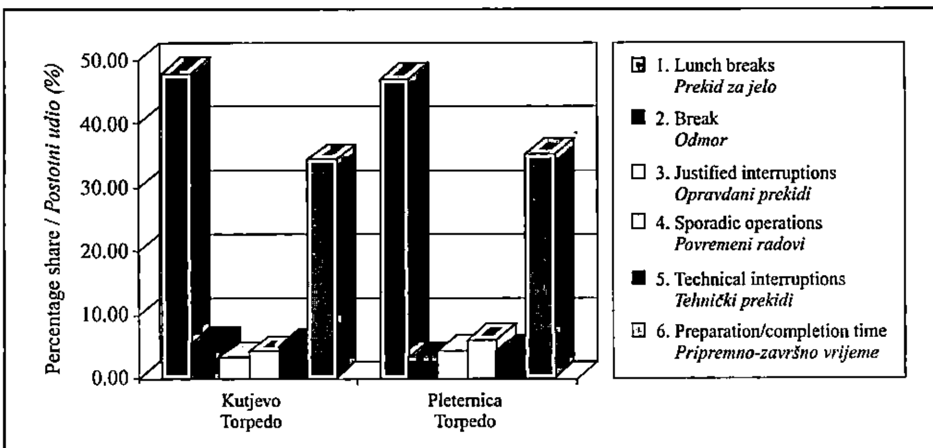
Type of time or work interruption *Vrsta vremena ili prekida rada*	Torpedo TD 75A			
	Kutjevo		Pleternica	
	Time *Vrijeme*	Percentage *Postotni udio*	Time *Vrijeme*	Percentage *Postotni udio*
	min	%	min	%
1. Lunch break *1. Prekid za jelo*	401.00	47.87	240.00	47.05
2. Break and personal needs *2. Odmor i osobne potrebe*	45.45	5.43	16.47	3.23
3. Justified interruptions *3. Opravdani prekidi*	26.97	3.22	22.10	4.33
4. Sporadic operations *4. Povremeni radovi*	34.70	4.14	30.84	6.05
5. Technical interruptions *5. Tehnički prekidi*	42.71	5.10	21.48	4.21
6. Preparation/completion time *6. Pripremno-završno vrijeme*	286.8	34.24	179.22	35.13
7. Allowance time *7. Dodatno vrijeme*	837.63	100.00	510.11	100.00

or 26.2% of effective time. The establishment of allowance time was based on an analysis of each interruption. A lunch break lasting 30 minutes was acknowledged for 8 hours of work. At Kutjevo this amounted to 47.87%, and at Pleternica to 47.05% of allowance time. Time for rest and personal needs at Kutjevo amounted to 5.43%, and at Pleternica it came to 3.23% of allowance time. Sporadic jobs amounted 4.14% and 6.05% of this time at the respective sites. Technical interruptions amounted to 5.1% and 4.21% of allowance time, and were acknowledged based on an evaluation of the time required for repairs. Preparation/completion time at Kutjevo amounted to 34.24%, and at Pleternica to 35.13% of allowance time.

For adapted agricultural tractors, Bojanin (1975) gives allowance time ranging from 11.7% to 38.4%, and Krpan (1984), for all other tractors, gives a range of 13.4% to 25.8%.

Figure 11 shows the share of allowance time at both work sites. It is evident that the lunch break took the largest share, followed by preparation/completion time, whereas other times are evenly represented.

Figure 11. Allowance time in skidding timber with a Torpedo TD 75A tractor
Slika 11. Dodatno vrijeme pri privlačenju drva traktorom Torpedo TD 75A



TOTAL TIME CONSUMPTION OF THE ECOTRAC V-11-1033F TRACTOR
UKUPNO UTROŠENA VREMENA TRAKTORA ECOTRAC V-11-1033F

Table 18 shows the total time consumption of Ecotrac tractors at both work sites, and the share of individual time in the total and effective time. At the Kutjevo work site, the work of the tractor was measured over 15 days, and at the Pleternica work site over 8 days.

A total of 134 tractor cycles were measured at Kutjevo, and 47 at Pleternica, which made a total of 181 tractor cycles. At the Kutjevo work site, 6,295.08 minutes of work were measured, and at Pleternica, 3,418.74 minutes. Effective time at Kutjevo was 9.11% longer than at Pleternica. Delay time at Kutjevo amounted to 48.54%, and to 57.65% at Pleternica. Effective time per unit amounted to 21.64 min/m^3 and 26.18 min/m^3 respectively. At Pleternica, 4.54% more net time was spent than at Kutjevo. The total time per unit at Kutjevo amounted to 42.05 min/m^3, while at Pleternica it was 19.77 minutes more, amounting to 61.82 min/m^3.

Table 18. Structure of total time consumption of an Ecotrac V-11-1033F tractor
Tablica 18. Struktura ukupno utrošenih vremena traktora Ecotrac V-11-1033F

Type of operations *Vrsta aktivnosti*	Time consumption *Utrošak vremena*					
	Ecotrac - Kutjevo			Ecotrac - Pleternica		
	Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema*		Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema*	
		total time *ukupnom vremenu*	effective time *efektivnom vremenu*		total time *ukupnom vremenu*	effective time *efektivnom vremenu*
	min	%		min	%	
1. Unloaded tractor travell *1. Vožnja neopterećenog traktora*	276.31	4.39	8.53	157.07	4.59	10.85
2. Loaded tractor travell *2. Vožnja opterećenog traktora*	291.01	4.62	8.98	171.42	5.01	11.84
3. Felling site work *3. Rad na sječini*	2 130.57	33.85	65.77	621.60	18.18	42.93
3.1. Taking up a position *3.1. Zauzimanje položaja*	78.47	1.25	2.42	36.55	1.07	2.52
3.2. Pulling out of rope *3.2. Izvlačenje užeta*	166.30	2.64	5.13	58.84	1.72	4.06
3.3. Binding load (tractor driver) *3.3. Vezanje tovara (traktorist)*	421.38	6.69	13.01	348.86	10.20	24.09
3.4. Skidding and lifting load *3.4. Privitlavanje i podizanje tovara*	87.64	1.39	2.71	13.74	0.40	0.95
3.5. Fixing load *3.5. Ispravljanje tovara*	145.02	2.30	4.48	49.67	1.45	3.43
3.6. Winching *3.6. Privitlavanje*	177.03	2.81	5.47	59.04	1.73	4.08
3.7. Move up and down *3.7. Silaženje i penjanje*	68.02	1.08	2.10	28.17	0.82	1.95
3.8. Preparing and binding load *3.8 Priprema i vezanje tovara sjekača*	986.71	15.67	30.46	26.73	0.78	1.85

4. Auxiliary landing work *4. Rad na pomoćnom stovarištu*	541.32	8.60	16.71	497.85	14.56	34.38
4.1. Loaded tractor travell *4.1. Vožnja opterećenog traktora*	57.31	0.91	1.77	108.90	3.19	7.52
4.2 Winching *4.2. Privitlavanje*	1.42	0.02	0.04	0.29	0.01	0.02
4.3. Move up and down *4.3. Silaženje i penjanje*	46.91	0.75	1.45	25.64	0.75	1.77
4.4. Unfastening load *4.4. Odvezivanje tovara*	244.52	3.88	7.55	160.34	4.69	11.07
4.5. Unbinding rope *4.5. Izvlačenje užeta*	1.28	0.02	0.04	25.69	0.75	1.77
4.6. Making a wood stack *4.6. Uređenje složaja*	105.69	1.68	3.26	97.09	2.84	6.71
4.7. Unloaded tractor turning *4.7. Okretanje neopterećenog traktora*	30.65	0.49	0.95	9.57	0.28	0.66
4.8. Unloaded tractor travell *4.8. Vožnja neopterećenog traktora*	53.54	0.85	1.65	70.33	2.06	4.86
5. Effective time *5. Efektivno vrijeme*	3 239.21	51.46	100.00	1 447.94	42.35	100.00
6. Delay times *6. Opća vremena*	3 055.87	48.54	-	1 970.80	57.65	-
7. Total time *7. Ukupno vrijeme*	6 295.08	100.00	-	3 418.74	100.00	-
8. Total skidded timber volume, m^3 *8. Ukupno privučeni drvni obujam, m^3*	149.70	-	-	55.31	-	-
9. Effective time per unit, min/m^3 *9. Efektivno vrijeme po jedinici, min/m^3*	21.64	-	-	26.18	-	-
10. Total time per unit, min/m^3 *10. Ukupno vrijeme po jedinici, min/m^3*	42.05	-	-	61.82	-	-
11. Realised daily output, m^3/day *11. Ostvareni dnevni učinak, m^3/dan*	9.98	-	-	6.91	-	-

THE ALLOWANCE TIME OF AN ECOTRAC V-11-1033F TRACTOR
DODATNO VRIJEME TRAKTORA ECOTRAC V -11-1033F

Table 19 shows the structure of allowance time for an Ecotrac tractor. The allowance time of an Ecotrac tractor at Kutjevo amounted to 26.8%. At Pleternica the allowance time of the tractor amounted to 32.8%. If the lunch break of 393.44 minutes and 213.67 minutes is deducted, then the allowance time of the Ecotrac tractor at Kutjevo amounts to 14.6% of effective time, while at Pleternica it comes to 18.1%.

Table 19. Structure of allowance time of an Ecotrac V-11-1033F
Tablica 19. Struktura dodatnog vremena traktora Ecotrac V-11-1033F

Type of time or work interruption *Vrsta vremena ili prekida rada*	Ecotrac V 1033F			
	Kutjevo		Pleternica	
	Time *Vrijeme*	Percentage *Postotni udio*	Time *Vrijeme*	Percentage *Postotni udio*
	min	%	min	%
1. Lunch break *1. Prekid za jelo*	393.44	45.31	213.67	44.94
2. Break and personal needs *2. Odmor i osobne potrebe*	86.42	9.95	29.95	6.30
3. Justified interruptions *3. Opravdani prekidi*	64.03	7.37	18.86	3.97
4. Sporadic operations *4. Povremeni radovi*	0.00	0.00	13.98	2.94
5. Technical interruptions *5. Tehnički prekidi*	27.89	3.21	40.89	8.60
6. Preparation/completion time *6. Pripremno-završno vrijeme*	296.48	34.15	158.07	33.25
7. Allowance time *7. Dodatno vrijeme*	868.26	100.00	475.42	100.00

Rest and personal needs amounted to 9.95% and 6.30%, and justified interruptions to 7.37% and 3.97% at the respective sites. Sporadic jobs took place only at the Pleternica work site and amounted to 2.94% of allowance time. Technical interruptions amounted to 3.21% and 8.60% respectively, and were recognised in the same way as for the Torpedo tractors.

Figure 12 shows a histogram of the structure of allowance time for both tractors. It is evident that the largest share is taken up by the lunch break, followed by preparation/completion time. Other times are represented with marginal differences.

Figure 13 shows the relationship of effective and delay time for Torpedo and Ecotrac tractors at both work sites. It can be seen that the Torpedo tractor at Kutjevo achieved 8%, the Ecotrac at Kutjevo, 2.82%, and the Torpedo at Pleternica just 0.82% more effective time in relation to delay time. The shortest effective time in the total working time was achieved by the Ecotrac tractor at Pleternica, amounting to only 42.35%.

Figure 12. Allowance skidding time of an Ecotrac V-11-1033F tractor
Slika 12. Dodatno vrijeme privlačenja drva traktorom Ecotrac V-11-1033F

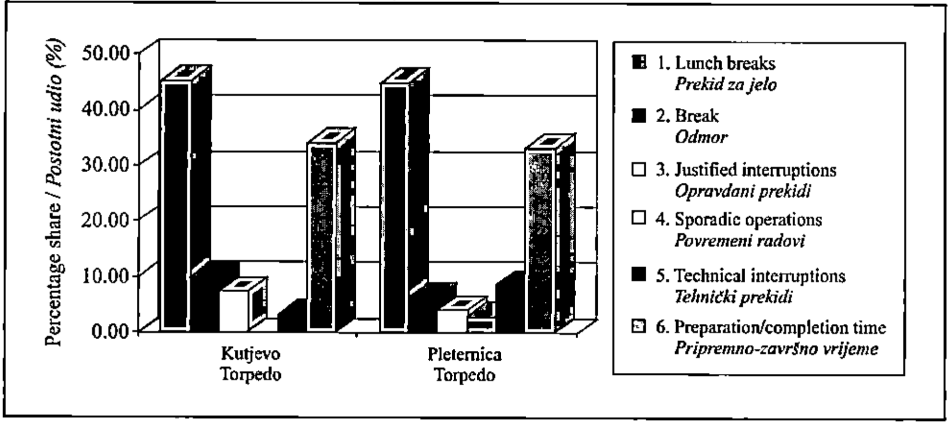
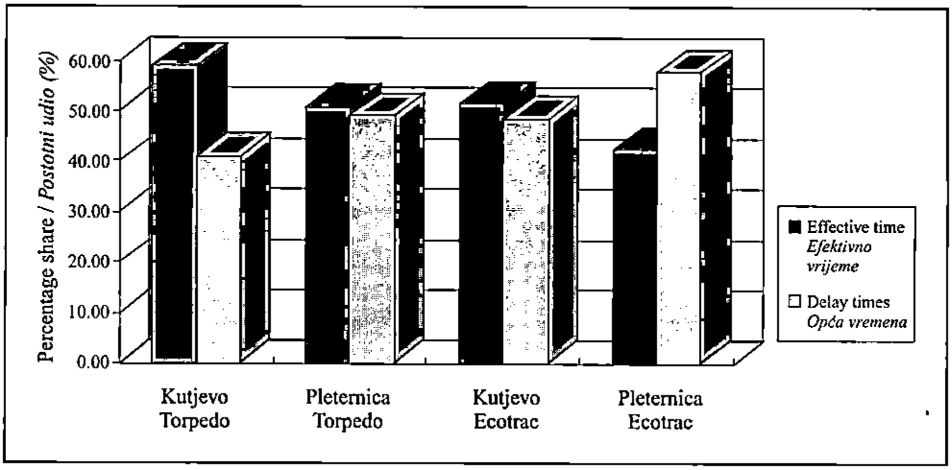


Figure 13. The relationship between effective and delay time in the total time consumption per work sites and tractors
Slika 13. Odnos efektivnog i općih vremena u ukupno utrošenom vremenu po radilištima i traktorima



SOME AVERAGE MEASUREMENTS AT THE WORK SITES
NEKE PROSJEČNE VELIČINE NA RADILIŠTIMA

As can be seen in Table 20, the mean skidding distance ranged between 254 m and 344 m. The average daily output ranged between 6.91 m^3/day with the Ecotrac tractor at Pleternica, and 11.43 m^3/day with the Torpedo at Kutjevo. The average realised working time per day was between 83.5% to 89% of an 8-hour working day.

Table 20. Some average measurements achieved at the work sites
Tablica 20. Neke prosječno ostvarene veličine na radilištima

Tractor Working site *Traktor Radilište*	Mean skidding distance *Srednja udaljenost privlačenja*	Total cycles time *Ukupno vrijeme turnusa*	Number of cycles per day *Broj turnusa dnevno*	Mean load volume *Srednji obujam tovara*	Output norm *Norma učinka*	Time consumption per product unit *Utrošak vremena po jedinici proizvoda*	Average time consumption per day *Prosječno utrošeno vrijeme po danu*	
	mm	min		m^3	m^3/day *m^3/dan*	min/m^3 *min/m^3*	min	% of 480 min *% od 480 min*
Torpedo Kutjevo	254	41.44	9.7	1.20	11.43	35.04	400.59	83.5
Ecotrac Kutjevo	238	45.13	9.3	1.12	9.98	42.05	419.67	87.4
Torpedo Pleternica	326	68.62	6.2	1.58	9.84	43.22	425.42	88.6
Ecotrac Pleternica	344	72.43	5.9	1.18	6.91	61.82	427.34	89.0

CYCLE TIMES
VREMENA TURNUSA

TIME DISTRIBUTION OF TRACTOR CYCLES
RASPODJELA VREMENA TURNUSA TRAKTORA

Data on the distribution of cycle times are shown in Tables 21 and 22. All the work elements were processed by mathematical statistical methods.

THE TIME STRUCTURE OF TRACTOR CYCLES – KUTJEVO
STRUKTURA VREMENA TURNUSA TRAKTORA - KUTJEVO

The effective time of the cycles of the TK (Torpedo Kutjevo) amounted to 26.84 minutes or to 80.9% of the total cycle times. With the allowance time of 23.6%, the total cycle time was 33.18 minutes. Table 21 also shows the values of the average load volume and the achieved average standard times and daily outputs. Work at the felling site lasted 14.91 minutes, or 55.5% of net time, and the least time, 2.99 minutes, or 11.1%, was spent on driving an unloaded tractor along the skid trail and felling site. When the work was done at the felling site, the tractor driver spent 4.02 minutes or 15.0% in binding the load, while the cutter spent 4.70 minutes or 17.5% of effective time. Binding the load lasted for a total of 8.72 minutes, or 32.5% of effective time. The operation of securing and balancing the load amounted to 8.4% of effective time, while the other working operations at the felling site take up a significantly smaller proportion of time.

Table 21. Time structure of cycles for a skidding distance of 300 m along the skid trail and the felling site, and a distance of 100 m along the auxiliary landing, TK (Torpedo Kutjevo) and EK (Ecotrac Kutjevo)

Tablica 21. Struktura vremena turnusa za udaljenost privlačenja po vlaci i sječini od 300 m i po pomoćnom stovarištu 100 m, TK (Torpedo Kutjevo) i EK (Ecotrac Kutjevo)

Type of time *Vrsta vremena*	Torpedo Kutjevo (TK)			Ecotrac Kutjevo (EK)		
	Cycle consumption time *Utrošak vremena turnusa*			Cycle consumption time *Utrošak vremena turnusa*		
	min	Percentage per *Postotni udio prema*		min	Percentage per *Postotni udio prema*	
		total time *ukupnom vremenu*	effective time *efektivnom vremenu*		total time *ukupnom vremenu*	effective time *efektivnom vremenu*
		%			%	
1. Unloaded tractor travell *1. Vožnja neopterećenog traktora*	2.99	9.0	11.1	2.81	8.7	11.0
2. Loaded tractor travell *2. Vožnja opterećenog traktora*	3.47	10.5	12.9	2.81	8.7	11.0
3. Felling site work *3. Rad na sječini*	14.91	44.9	55.5	15.16	46.8	59.4
3.1 Taking up a position *3.1 Zauzimanje položaja*	1.05	3.2	3.9	0.56	1.7	2.2
3.2 Pulling out of rope *3.2 Izvlačenje užeta*	1.03	3.1	3.8	1.19	3.7	4.7
3.3 Binding load (tractor driver) *3.3 Vezanje tovara (traktorist)*	4.02	12.1	15.0	3.03	9.4	11.9
3.4 Winching and lifting load *3.4 Privitlavanje i podizanje tovara*	0.01	0.0	0.0			
3.5 Fixing load *3.5 Ispravljanje tovara*	2.26	6.8	8.4	1.04	3.2	4.1
3.6 Winching *3.6 Privitlavanje*	1.31	4.0	4.9	1.74	5.3	6.8
3.7 Move up and down *3.7 Silaženje i penjanje*	0.53	1.6	2.0	0.49	1.5	1.9
3.8 Preparation and binding cutter's load *3.8 Priprema i vezanje tovara sjekača*	4.70	14.2	17.5	7.10	21.9	27.8

4. Auxiliary landing wok *4. Rad na pomoćnom stovarištu*	5.48	16.5	20.4	4.76	14.7	18.6
4.1 Loaded tractor travell *4.1 Vožnja opterećenog traktora*	1.16	3.5	4.3	1.03	3.2	4.0
4.2 Winching *4.2 Privitlavanje*	0.02	0.0	0.1	0.01	0.0	0.0
4.3 Move up and down *4.3 Silaženje i penjanje*	0.48	1.4	1.8	0.34	1.0	1.3
4.4 Unbinding load *4.4 Odvezivanje tovara*	1.37	4.1	5.1	1.76	5.4	6.9
4.5 Hauling rope *4.5 Izvlačenje užeta*	0.04	0.1	0.1	0.01	0.0	0.0
4.6 Making a wood stack *4.6 Uređenje složaja*	1.45	4.4	5.4	0.76	2.3	3.0
4.7 Turning of unloaded tractor *4.7 Okretanje neopterećenog traktora*	0.14	0.4	0.5	0.22	0.7	0.9
4.8 Unloaded tractor travell *4.8 Vožnja neopterećenog traktora*	0.83	2.5	3.1	0.63	1.9	2.5
5. Effective time *5. Efektivno vrijeme*	26.84	80.9	100.0	25.54	78.9	100.0
6. Allowance time (23.6 % to effective time) *6. Dodatno vrijeme (23.6 % na efek. vrij.)*	6.34	19.1		6.84	21.1	
7. Total cycle time *7. Ukupno vrijeme turnusa*	33.18	100.0		32.38	100.0	
8. Average load volume, m^3 *8. Prosječan obujam tovara, m^3*	1.20			1.12		
9. Time standard, min/m^3 *9. Norma vremena, min/m^3*	27.65			28.91		
10. Daily output, m^3/day *10. Dnevni učinak, m^3/dan*	17.36			16.60		

In working at the auxiliary landing, most time was consumed on arranging the stack 1.45 minutes, or 5.4% of effective time. This was followed by unloading at 5.1%, and driving the loaded tractor, at 4.3% of effective cycle time (Table 21).

Most time was spent on working at the felling site, 55.5% of effective cycle time for the TK, and 51.9% for the TP (Torpedo Pleternica). At the felling site, most time was spent on binding the load. At the auxiliary landing, the Torpedo at Kutina spent 20.4%, and the Torpedo at Pleternica, 7.6% more effective cycle time. The time for driving the loaded and unloaded tractor differed marginally for both tractors.

Table 21 also shows the time structure of the EK (Ecotrac Kutjevo) tractor cycles. Effective time amounted to 24.54 minutes, or 78.9%, and allowance time to 6.84 minutes, or 21.1% of total cycle time. The table also gives the figures of an average load volume, the standard time and daily output. Work at the felling site lasted 15.16 minutes, or 59.4%, and the least time was spent on driving a loaded and unloaded tractor along the skid trail and felling site – 2.81 minutes, or 11.0%. Work at the auxiliary landing with an EK tractor amounted to 4.76 minutes, or 14.7% of effective, or 18.6% of total time.

When working at the felling site with an Ecotrac tractor at Kutjevo, most time was spent on binding the cutter's load – 7.10 minutes, or 27.8% – and in binding the tractor driver's load – 3.03 minutes, or 11.9% of effective time. The total time for binding the load amounted to 10.13 minutes, or to 39.7% of the effective cycle time. The other working operations were represented in a range from 1.8% to 3.9% of effective cycle time.

The Ecotrac tractor at Kutjevo spent 4.76 minutes, or 18.6% of effective cycle time, at the auxiliary landing. Within working time, most time was spent on unloading – 1.76 minutes, or 6.9% – and on driving the loaded tractor – 1.03 minutes, or 4.0% of effective time.

TIME STRUCTURE OF TRACTOR CYCLES – PLETERNICA
STRUKTURA VREMENA TURNUSA TRAKTORA - PLETERNICA

The time structure of the tractor cycles of the TP (Torpedo Pleternica) and EP (Ecotrac Pleternica) is shown in Table 22. The effective time of a Torpedo tractor cycle at the Pleternica work site amounted to 36.10 minutes, or to 79.2% of total cycle time.

Allowance time amounted to 26.2%, or as an absolute amount to 9.46 minutes. The total time of a cycle was 45.56 minutes. Work at the felling site lasted 18.72 minutes, or 51.9%, and work at the auxiliary landing lasted 10.10 minutes, which is 8.62 minutes, or 46.0%, less than loading time. The least time was consumed in driving an unloaded tractor along the skid trail and the felling site – 3.10 minutes or 8.6%. Apart from effective and delay times, Table 22 also shows the figures for an average load volume, the standard time and daily output.

Driving an unloaded TP tractor along the skid trail and the felling site took 2.5% less time, and driving a loaded tractor took 1.3% less effective cycle time than the TK. The working time of the TP at the felling site was 3.6% shorter than that of the TK. In this time, the time spent on binding the tractor operator's load at Pleternica was 7.4% longer, and the time for binding the cutter's load was 16.0% of effec-

Table 22. Time structure of cycles for a skidding distanceof 300 m along the skid trail and the felling site, and distance of 100 m along theauxiliary landing, Torpedo Pleternica (TP) and Ecotrac Pleternica (EP)

Tablica 22. Struktura vremena turnusa za udaljenost privlačenja po vlaci i sječini od 300 m i po pom. stovarištu 100 m, Torpedo Pleternica (TP) i Ecotrac (Pleternica)

Type of time *Vrsta vremena*	Torpedo Pleternica (TP)			Ecotrac Pleternica (EP)		
	Cycle consumption time *Utrošak vremena turnusa*			Cycle consumption time *Utrošak vremena turnusa*		
	min	Percentage per *Postotni udio prema*		min	Percentage per *Postotni udio prema*	
		total time *ukupnom vremenu*	effective time *efektivnom vremenu*		total time *ukupnom vremenu*	effective time *efektivnom vremenu*
		%			%	
1. Unloaded tractor travell *1. Vožnja neopterećenog traktora*	3.10	6.8	8.6	4.02	9.5	12.6
2. Loaded tractor travell *2. Vožnja opterećenog traktora*	4.18	9.2	11.6	4.64	10.9	14.5
3. Felling site work *3. Rad na sječini*	18.72	41.1	51.9	13.17	31.0	41.1
3.1 Taking up a position *3.1 Zauzimanje položaja*	1.20	2.6	3.3	0.78	1.8	2.4
3.2 Pulling out of rope *3.2 Izvlačenje užeta*	1.79	3.9	5.0	1.25	2.9	3.9
3.3 Binding load (tractor driver) *3.3 Vezanje tovara (traktorist)*	8.10	17.8	22.4	7.42	17.5	23.2
3.4 Fixing load *3.4 Ispravljanje tovara*	3.51	7.7	9.7	1.06	2.5	3.3
3.5 Winching *3.5 Privitlavanje*	2.96	6.5	8.2	1.49	3.5	4.6
3.6 Move up and down *3.6 Silaženje i penjanje*	0.64	1.4	1.8	0.60	1.4	1.9
3.7 Preparation and binding cutter's load *3.7 Priprema i vezanje tovara sjekača*	0.53	1.2	1.5	0.57	1.3	1.8
4. Auxiliary landing work *4. Rad na pomoćnom stovarištu*	10.10	22.2	28.0	10.20	24.0	31.8
4.1 Loaded tractor travell *4.1 Vožnja opterećenog traktora*	1.19	2.6	3.3	1.81	4.3	5.7

4.2 Winching *4.2 Privitlavanje*				0.01	0.0	0.0
4.3 Move up and down *4.3 Silaženje i penjanje*	0.51	1.1	1.4	0.55	1.3	1.7
4.4 Unbinding load *4.4 Odvezivanje tovara*	4.72	10.4	13.1	3.41	8.0	10.7
4.5 Hauling rope *4.5 Izvlačenje užeta*	0.35	0.8	1.0	0.55	1.3	1.7
4.6 Making a wood stack *4.6 Uređenje složaja*	2.46	5.4	6.8	2.07	4.9	6.5
4.7 Turning of unloaded tractor *4.7 Okretanje neopterećenog traktora*	0.03	0.1	0.1	0.20	0.5	0.6
4.8 Unloaded tractor travell *4.8 Vožnja neopterećenog traktora*	0.84	1.8	2.3	1.61	3.8	5.0
5. Effective time *5. Efektivno vrijeme*	36.10	79.2	100.0	32.03	75.3	100.0
6. Allowance time (26.2 % to effective time) *6. Dodatno vrijeme (26.2 % na efek. vrij.)*	9.46	20.8		10.50	24.7	
7. Total cycle time *7. Ukupno vrijeme turnusa*	45.56	100.0		42.53	100.0	
8. Average load volume, m³ *8. Prosječan obujam tovara, m³*	1.58			1.18		
9. Time standard, min/ m³ *9. Norma vremena, min/m³*	28.84			36.04		
10. Daily output, m³/day *10. Dnevni učinak, m³/dan*	16.65			13.32		

tive cycle time shorter than at Kutjevo. The total binding time at Kutjevo amounted to 8.72 minutes, and at Pleternica it was only 0.09 minutes, or 1%, shorter.

The total working time at the Pleternica auxiliary landing was 4.62 minutes or 45.7% longer in relation to the TK. According to the structure and relationship of effective cycle time, the working time at the auxiliary landing at Pleternica was 7.6% longer in relation to the TK.

Table 22 also shows the structure of the EP (Ecotrac Pleternica) tractor cycles. In relation to total time, effective time amounted to 32.03 minutes, or to 75.3%, and allowance time amounted to 10.5 minutes, or to 24.7%. Work at the felling site amounted to 13.17 minutes, or to 41.1%, and at the auxiliary landing to 10.20 minutes or 31.8% of effective cycle time. The difference in time consumption amounted to 2.97 minutes, or to 22.6%. The least time was consumed in driving the unloaded tractor along the skid trail and the felling site – 4.02 minutes, or 12.6%. The table also shows the figures for an average load volume, and the standard times and daily outputs.

The Ecotrac at Pleternica spent 1.99 minutes or 13.1% less time on work at the felling site than the Ecotrac at Kutjevo. The Ecotrac at Kutjevo spent 10.3 minutes on binding the load, and the Ecotrac at Pleternica spent 2.31 minutes or 22.4% less time.

At the auxiliary landing, the Ecotrac at Pleternica spent 5.44 minutes or 53.3% more time than the Ecotrac at Kutjevo. Unloading took 1.65 minutes or 48.4% longer at Pleternica than it did at Kutjevo. To arrange the stack, the Ecotrac at Pleternica took 2.7 times longer than the Ecotrac in Kutjevo.

THE DRIVING TIME AND SPEED OF UNLOADED TRACTORS AT THE AUXILIARY LANDING
VRIJEME I BRZINE VOŽNJE NEOPTEREĆENIH TRAKTORA PO POMOĆNOM STOVARIŠTU

The driving time of unloaded tractors at the auxiliary landing and the speed for distances ranging between 25 and 350 m were calculated for both tractors and work sites by using regression analysis.

Table 23. Driving time and speeds of unloaded tractors at the auxiliary landing depending on skidding distance and average speed

Tablica 23. Vrijeme vožnje i brzine kretanja neopterećenih traktora po pomoćnom stovarištu u ovisnosti o udaljenosti privlačenja te prosječne brzine kretanja

Skidding distance *Udaljenost privlačenja*	Auxiliary landing travell - unloaded tractors *Vožnja po pomoćnom stovarištu - neopterećeni traktori*							
	Kutjevo				Pleternica			
	Torpedo (TK)		Ecotrac (EK)		Torpedo (TP)		Ecotrac (EP)	
	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*
m	min	km/h	min	km/h	min	km/h	min	km/h
50	0.49	6.10	0.39	7.74	0.65	4.58	0.96	3.11
100	0.83	7.23	0.63	9.56	0.84	7.11	1.62	3.71
150	1.17	7.70	0.87	10.37	1.03	8.72	2.27	3.97
200	1.51	7.96	1.11	10.83	1.22	9.83	2.92	4.11
250	1.85	8.13	1.35	11.13	1.41	10.65	3.57	4.20
300	2.18	8.24	1.59	11.34	1.60	11.27	-	-
350	2.52	8.32	-	-	-	-	-	-
Average speed *Prosječna brzina*		7.50		9.86		8.79		3.70

For the regression lines, Krpan (1984) states M. Kump's opinion of 1970 that the indices and coefficients of correlation that go above 0.75 show a strong connection. The author uses *Roemer-Orphal's* distribution to determine the strength of the correlation based on the calculated correlation coefficient:

Correlation coefficient	Correlation strength
0.0 – 0.1	no correlation
0.1 – 0.25	very weak
0.25 – 0.4	weak
0.4 – 0.5	medium
0.5 – 0.75	strong
0.75 – 0.9	very strong
0.9 – 1.0	complete correlation

Driving time of an unloaded Torpedo tractor (Kutjevo)
$y = 0.15341 + 0.00677\,x$, $r = 0.85975$; $fr = 0.25353$
Driving time of an unloaded Ecotrac tractor (Kutjevo)
$y = 0.14788 + 0.00480\,x$, $r = 0.92787$; $fr = 0.13764$
Driving time of an unloaded Torpedo tractor (Pleternica)
$y = 0.46634 + 0.00377\,x$, $r = 0.51085$; $fr = 0.56776$
Driving time of an unloaded Ecotrac tractor (Pleternica)
$y = 0.31336 + 0.01303\,x$, $r = 0.91177$; $fr = 0.39510$

The driving time and speed of unloaded tractors on the auxiliary landing for distances of 25 m to 350 m are shown in Table 23. The table also shows the average speeds of the tractors.

The auxiliary landing at Kutjevo is next to the main forest road along which the tractors are driven, while at Pleternica they move along a soft lorry track.

Speed is a function that combines time and distance. At the Kutjevo work site, a Torpedo tractor moved at an average speed of 7.50 km/h, and at the Pleternica work site, at a speed of 8.79 km/h, which showed the difference in the manner and personality of the tractor drivers. The speed of EK tractors at 25 m amounted to 5.60 km/h, and at 250 m, 11.34 km/h, which makes up an average of 9.86 km/h. At the Pleternica work site, the Ecotrac moved much more slowly, at an average speed of 3.70 km/h, or 2.7 times more slowly than the average speed of the EK, which we could attribute to the driver's personality. The Ecotrac driver at Kutjevo was more energetic, and the one at Pleternica more relaxed. Bojanin (1982) states that the working conditions affect speed by only 30%, while the drivers with their driving style affect it by 70%.

Krpan (1984) states that the speed of an unloaded IMT 558 tractor in lowland conditions on a microelevation on dry days amounts to 4.93 km/h, and on a microdepression on dry days it amounts to 6.77 km/h, and on rainy days it comes to 5.33 km/h and 6.38 km/h on the microelevation and the microdepression respectively. In skidding commercial roundwood with an unloaded adapted agricultural tractor, Bojanin (1982) gives a speed of 6.53 km/h at the auxiliary landing.

TIME AND SPEED OF LOADED TRACTORS AT THE AUXILIARY LANDING
VRIJEME I BRZINE VOŽNJE OPTEREĆENIH TRAKTORA PO POMOĆNOM STOVARIŠTU

The times and speed of loaded tractors at the auxiliary landing for distances ranging from 25 to 150 m at Kutjevo and from 25 to 300 m at Pleternica were equalised through regression analysis in the following manner:

Time of a loaded Torpedo tractor (Kutjevo)
$y = 0.29576 + 0.008663\ x$, $r = 0.70207$;$fr = 0.22569$
Time of a loaded Ecotrac tractor (Kutjevo)
$y = 0.10063 + 0.00927\ x$, $r = 0.80629$;$fr = 0.12294$
Time of a loaded Torpedo tractor (Pleternica)
$y = 0.46634 + 0.00377\ x$, $r = 0.51085$;$fr = 0.56776$
Time of a loaded Ecotrac tractor (Pleternica)
$y = 0.64912 + 0.011656\ x$, $r = 0.84804$;$fr = 0.51188$

In the driving of loaded tractors at the auxiliary landing at a distance of 50 m, the TP spent 0.79 minutes, that is, 0.06 minutes or 7.6% more than the TK (Table 24). At a distance of 100 m, the TP spent 1.16 minutes, and the TK 1.19 minutes, that is 0.03 minutes or 2.05% longer.

The speeds of the tractors at distances ranging from 25 to 300 m together with the average speed are shown in Table 24. The lowest average speed of 3.54 km/h was that of the EP tractor, and the highest one, of 5.59 km/h, which is 36.6% higher, was achieved by the TP tractor. The TK tractor moved at an average speed of 4.67 km/h, and the EK moved at an average of 5.28 km/h. The TK and TP tractors moved at an almost identical speed. There was a significant difference, though, between the EP and the EK tractors, with the relationship between speeds amounting to 1:1.5.

Loaded wheeler tractors moving on the auxiliary landing, according to Bojanin's study (1982), achieved an average speed of 4.19 km/h.

TIME AND SPEED OF UNLOADED TRACTORS ALONG THE SKID TRAIL AND AT THE FELLING SITE
VRIJEME I BRZINE VOŽNJE NEOPTEREĆENIH TRAKTORA PO VLACI I SJEČINI

The times of unloaded tractors and their speed along the skid trail and at the felling site are shown for both tractors and work sites in Table 25. The skidding distances ranged from 25 to 600 m. Unloaded tractors moved uphill along tractor trails. The mathematical form of regression is shown for each work operation as follows:

Times of an unloaded Torpedo tractor (Kutjevo) along the skid trail and the felling site:

$$y = 0.56770 + 0.00807x,\ \ r = 0.89103;\ fr = 0.42987$$

Table 24. Driving time and speeds of loaded tractors at the auxiliary landing depending on skidding distance and average speed

Tablica 24. Vrijeme vožnje i brzine kretanja opterećenih traktora po pomoćnom stovarištu u ovisnosti o udaljenosti privlačenja te prosječne brzine kretanja

Skidding distance *Udaljenost privlačenja*	Auxiliary landing travell - unloaded tractors *Vožnja po pomoćnom stovarištu - neopterećeni traktori*							
	Kutjevo				Pleternica			
	Torpedo (TK)		Ecotrac (EK)		Torpedo (TP)		Ecotrac (EP)	
	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*
m	min	km/h	min	km/h	min	km/h	min	km/h
50	0.73	4.12	0.55	5.41	0.79	3.79	1.23	2.44
100	1.16	5.16	1.09	5.52	1.19	5.04	1.81	3.31
150	1.60	5.64	-	-	1.59	5.65	2.40	3.75
200	-	-	-	-	1.99	6.02	2.98	4.03
250	-	-	-	-	2.39	6.27	3.56	4.21
300	-	-	-	-	2.79	6.45	4.15	4.34
Average speed *Prosječna brzina*		4.67		5.28		5.59		3.54

Times of an unloaded Ecotrac tractor (Kutjevo) along the skid trail and the felling site:

$$y = 0.52192 + 0.00761\,x,\ r = 0.91004;\ fr = 0.50213$$

Times of an unloaded Torpedo tractor (Pleternica) along the skid trail and the felling site:

$$y = 0.72907 + 0.00787\,x,\ r = 0.76993;\ fr = 0.71707$$

Time of an unloaded Ecotrac tractor (Pleternica) along the skid trail and the felling site:

$$y = 1.04522 + 0.0991\,x,\ r = 0.87636;\ fr = 0.76296$$

Table 25 shows the movement of unloaded tractors, their time consumption and how their speed develops for skidding distances from 50 to 600 m, as well as their average speeds.

In the driving of unloaded tractors along the skid trail and the felling site for distances of 100 m, the EK took the least time – 1.28 minutes, and the EP took the most time – 2.04 minutes, or 36.3% more than the EK. At a distance of 400 m, the EK took the least time – 3.57 minutes – and the EP the most time – 5.01 minute – or 25.5% more than the EK. In covering the same distance, Torpedo tractors took 3.80 minutes at Kutjevo, and at Pleternica 3.88 minutes.

The lowest average speed along the skid trail and the felling site of unloaded tractors was achieved by the Ecotrac tractor (Pleternica) – 4.09 km/h – and the highest – 5.97 km/h – by the Ecotrac tractor (Kutjevo).

Table 25. Driving time and speeds of unloaded tractors along the skid trail and the felling site depending on the skidding distance and the average speed
Tablica 25. Vrijeme vožnje i brzine kretanja neopterećenih traktora po vlaci i sječini u ovisnosti o udaljenosti privlačenja te prosječne brzine kretanja

Skidding distance *Udaljenost privlačenja*	Auxiliary landing travell - unloaded tractors *Vožnja po pomoćnom stovarištu - neopterećeni traktori*							
	Kutjevo				Pleternica			
	Torpedo		Ecotrac		Torpedo		Ecotrac	
	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*
m	min	km/h	min	km/h	min	km/h	min	km/h
50	0.97	3.09	0.90	3.32	1.12	2.67	1.54	1.95
100	1.38	4.36	1.28	4.68	1.52	3.96	2.04	2.95
150	1.78	5.06	1.66	5.41	1.91	4.71	2.53	3.55
200	2.18	5.50	2.04	5.87	2.30	5.21	3.03	3.96
250	2.59	5.80	2.42	6.19	2.70	5.56	3.52	4.26
300	2.99	6.02	2.81	6.42	3.09	5.83	4.02	4.48
350	3.39	6.19	3.19	6.59	3.48	6.03	4.51	4.65
400	3.80	6.32	3.57	6.73	3.88	6.19	5.01	4.79
450	4.20	6.43	3.95	6.84	4.27	6.32	5.51	4.90
500	4.60	6.52	4.33	6.93	-	-	6.00	5.00
550	5.01	6.59	4.71	7.01	-	-	6.50	5.08
600	5.41	6.65	5.06	7.11	-	-	-	-
Average speed *Prosječna brzina*		5.60		5.97		5.09		4.09

The lowest average speed along the skid trail and the felling site was 9.5% higher than the lowest average speed achieved at the auxiliary landing. The highest speed of unloaded tractors was achieved at the auxiliary landing, which was 39.5% higher than that along the skid trail and the felling site. Bojanin (1982 and 1980) gives a speed of 4.16 km/h for an unloaded adapted agricultural tractor moving on a mountainous area and 4.12 km/h for a lowland area. On a lowland area (Krpan 1984), unloaded IMT 558 tractors were reported to move on a microelevation at an average speed of 5.02 km/h, and on a microdepression and wet depression at 6.52 km/h and 6.70 km/h respectively.

THE TIME AND SPEED OF LOADED TRACTORS ALONG THE SKID TRAIL AND FELLING SITE
VRIJEME I BRZINE VOŽNJE OPTEREĆENIH TRAKTORA PO VLACI I SJEČINI

The times of loaded tractors along the skid trail and felling site and their speeds for distances ranging from 50 to 550 m are shown in Table 26 for both tractors.

Loaded tractors moved downhill along the skid trail and the felling site. Over a distance of 100 m, the Ecotrac tractor at Kutjevo took the least time – 1.61 minutes – and the most time was taken by the Ecotrac at Pleternica – 2.25 minutes. At 400 m, the Ecotrac at Kutjevo took 3.40 minutes, and the Ecotrac at Pleternica took the most time – 5.84 minutes.

For a distance of 100 m, a loaded Ecotrac tractor at Kutjevo took 0.33 minutes, or 20.5% more time than an unloaded one, and for a distance of 400 m, 0.17 minutes, or 4.8% less time than an unloaded tractor.

For a distance of 100 m, a loaded Ecotrac tractor at Pleternica took 0.21 minutes, or 9.3% more time than an unloaded one, and for 400 m, 0.83 minutes or 14.2% more time than an unloaded tractor. The regression equations are as follows:

Time of a loaded Torpedo tractor (Kutjevo) along the skid trail and the felling site:

$$y = 1.06325 + 0.00803\ x,\ r = 0.76690; fr = 0.65686$$

Time of a loaded Ecotrac tractor (Kutjevo) along the skid trail and the felling site:

$$y = 1.01757 + 0.00596\ x,\ r = 0.76841; fr = 0.71480$$

Time of a loaded Torpedo tractor (Pleternica) along the skid trail and the felling site:

$$y = 1.26979 + 0.00969\ x,\ r = 0.73579; fr = 0.98960$$

Table 26. Driving time and speeds of loaded tractors along the skid trail and the felling site, depending on skidding distance and average speed
Tablica 26. Vrijeme vožnje i brzine kretanja opterećenih traktora po vlaci i sječini u ovisnosti o udaljenosti privlačenja te prosječne brzine kretanja

Skidding distance *Udaljenost privlačenja*	Auxiliary landing travell - unloaded tractors *Vožnja po pomoćnom stovarištu - neopterećeni traktori*							
	Kutjevo				Pleternica			
	Torpedo		Ecotrac		Torpedo		Ecotrac	
	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*	Time consumption *Utrošak vremena*	Moving speed *Brzina kretanja*
m	min	km/h	min	km/h	min	km/h	min	km/h
50	1.46	2.05	1.32	2.28	1.75	1.71	1.66	1.81
100	1.87	3.22	1.61	3.72	2.24	2.68	2.25	2.66
150	2.27	3.97	1.91	4.71	2.72	3.31	2.85	3.16
200	2.67	4.50	2.21	5.43	3.21	3.74	3.45	3.48
250	3.07	4.89	2.51	5.98	3.69	4.06	4.05	3.71
300	3.47	5.18	2.81	6.41	4.18	4.31	4.64	3.88
350	3.87	5.42	3.10	6.77	4.66	4.51	5.24	4.01
400	4.27	5.61	3.40	7.05	5.14	4.67	5.84	4.11
450	4.68	5.77	3.70	7.30	5.63	4.80	6.44	4.19
500	-	-	4.00	7.50	-	-	7.03	4.26
550	-	-	4.30	7.68	-	-	-	-
Average speed *Prosječna brzina*		4.45		5.82		3.70		3.48

Time of a loaded Ecotrac tractor (Pleternica) along the skid trail and the felling site:

$$y = 1.05886 + 0.01195\ x,\ r = 0.79889; fr = 1.13172$$

The speeds of loaded tractors along the skid trail and the felling site are shown in Table 26. The lowest speed at 100 m was achieved by the Ecotrac (Pleternica) – 2.66 km/h, and the highest by the Ecotrac (Kutjevo) – 3.72 km/h.

At distances ranging from 50 to 100 m, the speeds of the tractors differed only marginally. At a distance of 450 m, the differences were significant, because the lowest speed of 4.19 km/h was recorded by the Ecotrac (Pleternica), and the highest speed of 7.30 km/h by the Ecotrac (Kutjevo), which was 42.6% higher.

The lowest average speed of 3.48 km/h was recorded by the Ecotrac (Pleternica), while the highest average speed of 5.92 km/h was achieved by the Ecotrac (Kutjevo), which is 41.2% higher. This difference cannot be justified by the mean volume of the load, which was almost identical – 1.12 m^3 and 1.18 m^3 respectively – but by the personality of one of the drivers.

The average speeds of loaded IMT 558 tractors in lowland conditions for dry weather (Krpan, 1984) ranged from 4.29 to 5.89 km/h. Bojanin (1982) records

Figure 14. Driving a loaded Ecotrac V – 11 – 1033F at the felling site
Slika 14. Vožnja opterećenog traktora Ecotrac V - 11 - 1033F po sječini

that adapted agricultural tractors in mountainous conditions achieved speeds of 5.03 and 2.64 km/h.

DAILY TIMES OF THE TEAM
DNEVNA VREMENA SKUPINE

EFFECTIVE AND ALLOWANCE TIME OF THE TEAM
EFEKTIVNO I DODATNO VRIJEME SKUPINE

Table 27 shows the effective and allowance time for parts of a team and the time of a team in one day. At the Kutjevo work site the team worked in pairs. The first pair consisted of a cutter and a tractor driver with a Torpedo tractor, and the second pair consisted of a cutter and a tractor driver with an Ecotrac.

The first pair spent 318.16 min/day of effective time. The cutter spent this time in cutting trees of a mean DBH of 20.2 cm and the tractor in skidding loads of a mean volume of 1.20 m^3 at an average distance of 254 m.

The second pair spent 302.55 min/day of effective time. The cutter spent this time in cutting trees of a mean DBH of 21.1 cm, and the tractor driver in skidding loads of a mean volume of 1.12 m^3 at an average distance of 238 m.

Allowance time amounted to 149.66 min/day for the first pair and 149.71 min/day for the second pair.

Inspection at the auxiliary landing was carried out by one cutter and it took him only 62.38 min/day of effective time and 42.01 min/day of allowance time, which made up a total of 104.39 min/day, or 10.2% of team time. Total inspection time took up 21.7% of a 480-minute long working day.

Effective team time at Kutjevo amounted to 683.09 min/day or 66.7% of total time. Allowance time amounted to 341.38 min/day or 33.3% of total team time. The time of felling and processing for both cutters amounted to 164.06 min/day or to 16%, and allowance time to 185.65 min/day or to 18.1% of total team time. The consumption of time for both cutters on binding the tractor load amounted to 111.24 min/day or to 10.9% of total team time.

Effective time for the work of the cutter and the tractor amounted to 620.71 min/day, or to 60.6% of total time, that is, to 90.9% of effective team time.

At the Pleternica work site, one cutter and two tractors achieved the effective time of 547.01 min/day, or of 58.8% of total time, that is, 85.8% of effective team time. Allowance time amounted to 222.43 min/day or to 23.9% of total time. The Torpedo tractor skidding at Pleternica achieved 213 min/day, while the Ecotrac tractor achieved 157.91 min/day, that is, 371.18 min/day, or 39.9% of total time, that is, 58.2% of effective team time for both tractors together.

The cutters' allowance time amounted to 112.93 min/day or to 12.1%, and that of tractor drivers amounted to 11.8% of total team time, which makes a total of 23.9%.

The total times of cutters and tractors amounted to 769.44 min/day or to 82.7% of total team time.

Table 27. Times of a team according to the working day and work sites
Tablica 27. Vremena skupine po radnom danu i radilištima

Type of time and working operations *Vrsta vremena i radnih zahvata*		Team in Kutjevo *Skupina u Kutjevu*					Team in Pleternica *Skupina u Pleternici*				
		Cutter and Torpedo *Sjekač i Torpedo*	Cutter and Ecotrac *Sjekač i Ecotrac*	Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema*		Torpedo	Ecotrac	Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema*	
					total time *ukupnom vemenu*	effective time *efektivnom vremenu*				total time *ukupnom vremenu*	effective time *efektivnom vremenu*
		min/day *min/dan*			%		min/day *min/dan*			%	
Effective time *Efektivno vrijeme*	Cutting and processing *Sječa i izradba*	77.62	86.44	164.06	16.0	24.0	169.53		169.53	18.2	26.6
	Binding load *Vezanje tovara*	45.46	65.78	111.24	10.9	16.3	6.3		6.30	0.7	1.0
	Auxiliary landing work *Rad na pomoćnom stovarištu*	4.19	0.16	4.35	0.4	0.6	-		0.00	0.0	0.0
	Skidding *Privlačenje**	190.89	150.20	341.06	33.3	49.9	213.27	157.9	371.18	39.9	58.2
	Total time *Ukupno vrijeme*	318.16	302.60	620.71	60.6	90.9	547.01		547.01	58.8	85.8
Allowance time *Dodatno vrijeme*	Cutter *Sjekač*	93.82	91.83	185.65	18.1		112.93		112.93	12.1	

	Tractor *Traktor*	55.84	57.88	113.72	11.1		56.68	52.82	109.50	11.8	
	Total time *Ukupno vrijeme*	149.66	149.70	299.37	29.2		222.43		222.43	23.9	
Total cutter and tractor, min *Ukupno sjekač i traktor, min*		467.82	452.30	920.08	89.8		769.44		769.44	82.7	
Timber inspection *Preuzimanje*	Effective time *Efektivno vrijeme*			62.38	6.1	9.1			90.61	9.7	14.2
	Allowance time *Dodatno vrijeme*			42.01	4.1				70.89	7.6	
	Total time *Ukupno vrijeme*			104.39	10.2				161.50	17.3	
Team time *Vrijeme skupine*	Effective time *Efektivno vrijeme*			683.09	66.7	100.0			637.62	68.5	100.0
	Allowance time *Dodatno vrijeme*			341.38	33.3				293.32	31.5	
	Total time *Ukupno vrijeme*			1024.47	100.0				930.94	100.0	
Prescribed team time of 480 min/day x no. of members, min *Propisano vrijeme skupine od 480 min/dan x br. članova, min*				2400.0					1920.0		
Percentage of team time in total time, % *Postotni udio vremena skupine u ukupnom vremenu, %*				42.7					48.5		

*Mean skidding distance of tractors according to table 20 - * *Srednja udaljenost privlačenja traktora prema tablici 20*

A cutter at the Pleternica work site took 90.61 min/day or 9.7% of total time, that is, 14.2% of effective team time for inspection at the felling site. The proportion of inspection time amounted to 161.50 min/day, or to 17.3% of total team time. According to the daily time schedule of 480 minutes, this amounted to only 33.6%.

Effective team time at the Pleternica work site amounted to 637.62 min/day or to 68.5%, and allowance time amounted to 293.32 min/day, or to 31.5% of total team time.

The total time of the Kutjevo team amounted to 1,024.47 min/day or to 42.7%, and that of the Pleternica team amounted to 930.94 min/day or 48.5% of scheduled working time.

STANDARD TIME AND EFFICIENCY
NORME VREMENA I UČINKA

STANDARD TIMES AND DAILY OUTPUT OF CUTTERS
NORME VREMENA I DNEVNI UČINAK SJEKAČA

Different variants of the standard time of cutters are shown in Table 28. The cutters worked in three different forms of organisation, that is, in three different

Table 28. Standard times and daily output of cutters at felling, processing and inspection according to variants

Tablica 28. Norme vremena i dnevni učinak sjekača pri sječi, izradbi i preuzimanju po inačicama

Working operations *Radne operacije*			Working site Kutjevo *Radilište Kutjevo*					
			Cutter with Torpedo *Sjekač uz Torpedo*			Cutter with Ecotrac *Sjekač uz Ecotrac*		
			Effective time *Efektivno vrijeme*	Allowance time *Dodatno vrijeme*	Total time *Ukupno vrijeme*	Effective time *Efektivno vrijeme*	Allowance time *Dodatno vrijeme*	Total time *Ukupno vrijeme*
Variant 1 *Inačica 1*	Felling *Sječa*	min/m *min/m³*	4.07	1.05	5.12	4.07	1.05	5.12
	Processing separated from felling *Izradba odvojeno od sječe*		6.72	7.56	14.28	6.25	5.56	11.81
	Inspection at the auxiliary landing *Preuzimanje na pom. stov.*		6.21	4.19	10.40	6.21	4.19	10.40
	Total *Ukupno*		17.00	12.80	29.80	16.53	10.80	27.33
	Daily output, m³/day *Dnevni učinak, m³/dan*		16.11			17.56		

Variant 2 *Inačica 2*	Felling and processing simultaneously *Sječa i izradba istovrem.*	min/m *min/m³*	10.26	7.56	17.82	9.22	5.56	14.78
	Inspection at the auxiliary landing *Preuzimanje na pom. stov.*		6.21	4.19	10.4	6.21	4.19	10.4
	Total *Ukupno*		16.47	11.75	28.22	15.43	9.75	25.18
	Daily output, m³/day *Dnevni učinak, m³/dan*		17.01			19.06		
			Working site Pleternica *Radilište Pleternica*					
Variant 3 *Inačica 3*	Felling and processing simultaneously *Sječa i izradba istovrem.*	min/m *min/m³*	10.17	6.53	16.70			
	Inspection at the felling site *Preuzimanje u sječini*		5.16	4.18	9.34			
	Total *Ukupno*		15.33	10.71	26.04			
	Daily output, m³/day *Dnevni učinak, m³/dan*		18.43					

variants. In variant 1, the cutters cut the trees which they processed only 6 days later, which means that processing and felling were carried out at different times. In variant 2, the remaining standing trees were cut, and the felling and processing took place at the same time. The inspection of wood assortments for variant 1 and 2 was carried out at the auxiliary landing. In variant 3, cutting and processing was carried out at the same time, and the inspection followed immediately at the felling site after which finished wood assortments were skidded.

In variant 1, the total time of cutters with the TK amounted to 19.40 min/m³, and in variant 2 to 17.82 min/m³. The total time of cutters with the Ecotrac in variant 1 amounted to 16.93 min/m³, and in variant 2 to 14.78 min/m³. The inspection time for variants 1 and 2 amounted to an average of 10.4 min/m³. In variant 3, the total time of cutters amounted to 16.70 min/m³, of which 9.34 min/m³ for inspection.

The realised standard time was the lowest with cutters working alongside the Ecotrac in variant 2 – 25.18 min/m³ - and the highest with cutters working alongside the Torpedo in variant 1 – 29.80 min/m³.

According to the data shown in the Table, the daily output for 52 days amounted to 16.11 m³/day with cutters working alongside the Torpedo in variant 1, that is, 19.06 m³/day with cutters working alongside the Ecotrac in variant 2.

Allowance time ranged from 5.56 min/m³ with cutters working alongside the Torpedo in variant 1, to 6.53 min/m³ with cutters in variant 3 at Pleternica,

STANDARD TIME AND EFFICIENCY OF TRACTORS
NORME VREMENA I NORME UČINKA TRAKTORA

The standard time and efficiency of the Torpedo tractor at both work sites is shown in Table 29. At the Kutjevo work site, the standard time was calculated for a distance of 50 to 600 m, as the movement of the tractor was measured along the skid trail and the felling site. Table 30 shows the data of the Ecotrac tractor at both work sites for distances ranging from 50 to 550 m.

The standard time has been calculated as the average time consumed in skidding one unit of product over the mentioned distances, and its components are variable and fixed times, which make up effective time and allowance time. Variable time is made up of a sum of the times it takes to drive loaded and unloaded tractors along the skid trail, the felling site and the auxiliary landing, and fixed times are made up of all the working operations at the felling site and at the auxiliary landing.

From the total time consumed in one cycle and the average load volume, we can calculate the standard time per m³ of skidded timber. This ratio can be expressed with the following formula:

$$N_v = \frac{t}{q} \text{ (min/ m}^3\text{)}$$

where N = standard time, t = total time of one cycle (min)

q = average load volume (m³).

The daily output is calculated on the basis of the standard time or on the daily number of cycles and average load. When we use the standard time, the daily output is obtained by dividing the daily time in minutes by the respective quota. The number of cycles were calculated from the regulated work schedule (480 minutes) and total cycle time. The daily quota was calculated by multiplying the average number of daily cycles by the average load volume, as shown in the following formula:

$$U = N\,q \text{ (m}^3\text{/day)},$$

where U = daily output, N = number of cycles per day, q = average load volume (m³).

When calculating the decline in efficiency, the performance at a distance of 50 m is taken as value 1. With an increase in skidding distance, the daily output deteriorates, and this deterioration is best shown by the factor of the decline in efficiency.

Average efficiency is obtained on the basis of average data determined through mathematical-statistical methods, without evaluating the degree of efficiency

(Krpan, 1984). The degree of efficiency, according to the same author, is the ratio between real and regular efficiency. Regular efficiency is the output of a capable, skilful and thoroughly-well prepared worker, during and in the middle of the shift, who uses previously established breaks.

When calculating the standard time, usually the average output achieved is taken as the regular output. In teamwork, the tractor with all its features, as well as the conditions of the terrain, affect the performance of the cutter's daily output. According to the valid standard times at felling and processing, the daily output is recorded in the cutter's work order, so that he tries to fulfil the set task. When the tractor skidding distances are small, the cutter must engage more effort because he is preparing a larger quantity of wood, and when the distances are longer, he needs less effort to prepare smaller quantities of wood, so that the tractor can carry on with the skidding without waiting around.

The standard time and efficiency of the Torpedo and Ecotrac tractors are shown in Tables 29 and 30. The increasing trend of the standard time as distance grows is shown in Figure 15, and the tendency of the daily output to deteriorate with the increase in distance is presented in Figure 16.

Although the working conditions of all four tractors were similar, when calculating daily output, a great difference was seen between the Ecotrac at Pleternica and the other tractors. The decline in efficiency was the consequence of the lower speeds of loaded and unloaded tractors. According to Table 20, the average load volume of the Ecotrac tractor at Pleternica amounted to 1.18 m^3, while that of the Ecotrac at Kutjevo was 0.06m^3 smaller. The load of the Torpedo at Kutjevo was 0.02 m^3 larger, and that of the Torpedo at Pleternica was 0.04m^3 larger. The larger load volume had a direct impact on the daily output of the Torpedo at Pleternica when compared with the other tractors.

The unloaded Torpedo tractor at Kutjevo moving along the skid trail and felling site took 0.97 minutes at a distance of 50 m, and up to 5.41 minutes at a distance of 600 m. The Torpedo at Pleternica took 1.12 minutes for 50 m, and up to 4.27 minutes at a distance of 450 m.

The time of the unloaded Ecotrac at Kutjevo along the skid trail and the felling site ranged from 0.90 minutes for a distance of 50 m, to 4.71 minutes for a distance of 550 m. The Ecotrac at Pleternica took from 1.54 minutes for 50 m, to 6.50 minutes for a distance of 550 m (Table 30).

The time of the loaded Torpedo tractors at Kutjevo, moving along the skid trail and the felling site, ranged from 1.46 minutes for a distance of 50 m, to 5.88 minutes for a distance of 600 m. The time of the Torpedo at Pleternica ranged from 1.52 minutes for 50 m, to 5.63 minutes for a distance of 450 m.

The time of the loaded Ecotrac tractor on the Kutjevo work site ranged from 1.32 minutes for a distance of 50 m, to 4.30 minutes for a distance of 550 m. The Ecotrac at Pleternica took from 1.66 minutes to 7.63 minutes to cover the same distances.

The time consumption of the unloaded Torpedo tractor at the auxiliary landing at Kutjevo ranged from 0.49 minutes to 4.21 minutes for distances of 50 m to 450 m.

The unloaded Ecotrac tractor on the auxiliary landing at Kutjevo took from 0.39 minutes to 2.79 minutes for distances of 50 m to 550 m, and the Ecotrac at Pleternica from 0.96 minutes to 7.48 minutes to cover the same distances.

The loaded Torpedo tractor at the auxiliary landing at Kutjevo took from 0.73 minutes to 5.49 minutes for distances ranging from 50 to 600 m, and the Torpedo at Pleternica from 0.79 minutes to 3.99 minutes for distances from 50 to 450 m.

The time consumption of the loaded Ecotrac tractor at the auxiliary landing at Kutjevo ranged from 0.56 minutes to 5.20 minutes for distances from 50 to 550 m, and to cover the same distances the Ecotrac at Pleternica took 1.23 to 7.06 minutes.

The total variable times of the Torpedo at Kutjevo ranged from 3.66 minutes to 21.00 minutes for distances ranging from 50 m to 600 m, while those of the Torpedo at Pleternica ranged from 4.09 minutes to 16.06 minutes for distances from 50 to 450 m. The total variable times of the Ecotrac at Kutjevo ranged from 3.17 minutes to 16.99 minutes, and those of the Ecotrac at Pleternica from 5.39 minutes to 28.67 minutes for distances ranging from 50 to 550 m.

The fixed time of the Torpedo tractor at Kutjevo amounted to 19.59 minutes, of which work in the stand took 14.91 minutes and work at the auxiliary landing 4.68 minutes. The total fixed time of the Torpedo at Pleternica amounted to 29.05 minutes, of which work in the stand took 18.42 minutes, and work at the auxiliary landing 10.63 minutes. The total of the fixed time of the Ecotrac at Kutjevo amounted to 19.22 minutes, of which work in the stand took 15.33 minutes and work at the auxiliary landing 3.89 minutes. For the Ecotrac at Pleternica, the total fixed time amounted to 23.82 minutes, including 13.23 minutes of work in the stand and 10.59 minutes of work at the auxiliary landing.

Effective tractor working time is made up of the total of variable and fixed times for determined distances. For the Torpedo tractor at Kutjevo, this ranged from 23.25 minutes to 40.59 minutes for distances ranging from 50 to 600 m, and for the Torpedo at Pleternica, from 33.13 minutes to 45.10 minutes for distances from 50 to 450 m. The effective time of the Ecotrac at Kutjevo ranged from 22.39 minutes to 36.21 minutes, and that of the Ecotrac at Pleternica from 29.21 to 52.48 minutes for distances of 50 to 550 m.

Allowance time is determined as a percentage of effective time for each tractor separately, and is expressed in an absolute value. For the Torpedo at Kutjevo, it amounted to 23.6% of effective time and reached values from 5.49 minutes to 9.58 minutes. For the Torpedo at Pleternica, it amounted to 26.2% of effective time, and ranged from 8.68 minutes to 11.82 minutes. The percentage of allowance time of the Ecotrac at Kutjevo amounted to 26.8% of effective time, and ranged from 6 minutes to 9.71 minutes. For the Ecotrac at Pleternica, allowance time amounted to 32.8%, which, on the measured skidding distances, ranged from 9.58 to 17.21 minutes of absolute value.

The total time per cycle of the Torpedo at Kutjevo ranged from 28.73 minutes to 50.17 minutes, while that of the Torpedo at Pleternica was between the range of 41.81 and 56.92 minutes. The total time of the Ecotrac at Kutjevo ranged from

Table 29. Standard time and efficiency of the Torpedo TD 75A tractors
Tablica 29. Norme vremena i učinci traktora Torpedo TD 75A

Skidding distance *Udaljenost privlačenja*	Skidding line and felling site travell *Vožnja po vlaci i sječini*		Auxiliary landing travell *Vožnja po pomoćnom stovarištu*		Sum of variable times *Zbir varijabilnih vremena*	Feling site work *Rad u sastojini*	Auxiliary landing work *Rad na pomoćnom stovarištu*	Sum of fixed times *Zbir fiksnih vremena*	Effective time *Efektivno vrijeme*	Allo-wance time *Dodatno vrijeme*	Total time per cycle *Ukupno vrijeme po turnusu*	Time standard *Norma vremena*	Number of cycles per day *Broj vožnji dnevno*	Daily output *Dnevni učinak*	Output coeffi-cient decrease *Faktoro padanja učinka*
	Unloaded tractor *Neopte-rećeni traktor*	Loaded tractor *Opterećeni traktor*	Unloaded tractor *Neopterećeni traktor*	Loaded tractor *Opte-rećeni traktor*											
m / *m*	min / *min*											min/m³ *min/m³*		m³/day *m³/dan*	
Ecotrac - Kutjevo															
50	0.97	1.46	0.49	0.73	3.66	14.91	4.68	19.59	23.25	5.49	28.73	23.94	16.7	20.05	1.00
100	1.38	1.87	0.83	1.16	5.23	14.91	4.68	19.59	24.82	5.86	30.68	25.57	15.6	18.77	0.94
150	1.78	2.27	1.17	1.60	6.81	14.91	4.68	19.59	26.40	6.23	32.63	27.19	14.7	17.65	0.88
200	2.18	2.67	1.51	2.03	8.39	14.91	4.68	19.59	27.98	6.60	34.58	28.82	13.9	16.66	0.83
250	2.59	3.07	1.85	2.46	9.96	14.91	4.68	19.59	29.55	6.97	36.53	30.44	13.1	15.77	0.79
300	2.99	3.47	2.18	2.89	11.54	14.91	4.68	19.59	31.13	7.35	38.48	32.06	12.5	14.97	0.75
350	3.39	3.87	2.52	3.33	13.12	14.91	4.68	19.59	32.71	7.72	40.43	33.69	11.9	14.25	0.71
400	3.80	4.27	2.86	3.76	14.69	14.91	4.68	19.59	34.28	8.09	42.37	35.31	11.3	13.59	0.68
450	4.20	4.68	3.20	4.19	16.27	14.91	4.68	19.59	35.86	8.46	44.32	36.94	10.8	13.00	0.65
500	4.60	5.08	3.54	4.63	17.85	14.91	4.68	19.59	37.44	8.84	46.27	38.56	10.4	12.45	0.62
550	5.01	5.48	3.88	5.06	19.42	14.91	4.68	19.59	39.01	9.21	48.22	40.18	10.0	11.95	0.60
600	5.41	5.88	4.21	5.49	21.00	14.91	4.68	19.59	40.59	9.58	50.17	41.81	9.6	11.48	0.57
Ecotrac - Pleternica															
50	1.12	1.52	0.65	0.79	4.09	18.42	10.63	29.05	33.13	8.68	41.81	26.46	11.5	18.14	1.00
100	1.52	2.34	0.84	1.19	5.90	18.42	10.63	29.05	34.94	9.15	44.09	27.91	10.9	17.20	0.95
150	1.91	2.72	1.03	1.59	7.25	18.42	10.63	29.05	36.30	9.51	45.81	28.99	10.5	16.56	0.91
200	2.30	3.21	1.22	1.99	8.72	18.42	10.63	29.05	37.77	9.90	47.66	30.17	10.1	15.91	0.88
250	2.70	3.69	1.41	2.39	10.19	18.42	10.63	29.05	39.24	10.28	49.52	31.34	9.7	15.32	0.84
300	3.09	4.18	1.60	2.79	11.66	18.42	10.63	29.05	40.71	10.66	51.37	32.51	9.3	14.76	0.81
350	3.48	4.66	1.79	3.19	13.12	18.42	10.63	29.05	42.16	11.05	53.21	33.68	9.0	14.25	0.79
400	3.88	5.14	1.97	3.59	14.59	18.42	10.63	29.05	43.63	11.43	55.06	34.85	8.7	13.77	0.76
450	4.27	5.63	2.16	3.99	16.06	18.42	10.63	29.05	45.10	11.82	56.92	36.02	8.4	13.32	0.73

Table 30. Standard time and efficiency of Ecotrac tractors
Tablica 30. Norme vremena i učinci traktora Ecotrac

Skidding distance *Udaljenost privlačenja*	Skidding line and felling site travell *Vožnja po vlaci i sječini*		Auxiliary landing travell *Vožnja po pomoćnom stovarištu*		Sum of variable times *Zbir varijabilnih vremena*	Feling site work *Rad u sastojini*	Auxiliary landing work *Rad na pomoćnom stovarištu*	Sum of fixed times *Zbir fiksnih vremena*	Effective time *Efektivno vrijeme*	Allowance time *Dodatno vrijeme*	Total time per cycle *Ukupno vrijeme po turnusu*	Time standard *Norma vremena*	Number of cycles per day *Broj vožnji dnevno*	Daily output *Dnevni učinak*	Output coefficient decrease *Faktoro padanja učinka*
	Unloaded tractor *Neopterećeni traktor*	Loaded tractor *Opterećeni traktor*	Unloaded tractor *Neopterećeni traktor*	Loaded tractor *Opterećeni traktor*											
m / *m*	min / *min*											min/m³ *min/m³*		m³/day *m³/dan*	
Ecotrac - Kutjevo															
50	0.90	1.32	0,39	0.56	3.17	15.33	3.89	19.22	22.39	6.00	28.39	25.35	16.9	18.93	1.00
100	1.28	1.61	0.63	1.03	4.55	15.33	3.89	19.22	23.77	6.37	30.15	26.92	15.9	17.83	0.94
150	1.66	1.91	0.87	1.49	5.93	15.33	3.89	19.22	25.16	6.74	31.90	28.48	15.0	16.85	0.89
200	2.04	2.21	1.11	1.96	7.32	15.33	3.89	19.22	26.54	7.11	33.65	30.05	14.3	15.98	0.84
250	2.42	2.51	1.35	2.42	8.70	15.33	3.89	19.22	27.92	7.48	35.40	31.61	13.6	15.18	0.80
300	2.81	2.81	1.59	2.88	10.08	15.33	3.89	19.22	29.30	7.85	37.16	33.18	12.9	14.47	0.76
350	3.19	3.10	1.83	3.35	11.46	15.33	3.89	19.22	30.69	8.22	38.91	34.74	12.3	13.82	0.73
400	3.57	3.40	2.07	3.81	12.85	15.33	3.89	19.22	32.07	8.59	40.66	36.31	11.8	13.22	0.70
450	3.95	3.70	2.31	4.27	14.23	15.33	3.89	19.22	33.45	8.96	42.41	37.87	11.3	12.67	0.67
500	4.33	4.00	2.55	4.74	15.61	15.33	3.89	19.22	34.83	9.34	44.17	39.44	10.9	12.17	0.64
550	4.71	4.30	2.79	5.20	16.99	15.33	3.89	19.22	36.21	9.71	45.92	41.00	10.5	11.71	0.62
Ecotrac - Pleternica															
50	1.54	1.66	0.96	1.23	5.39	13.23	10.59	23.82	29.21	9.58	38.79	32.88	12.37	14.60	1.00
100	2.04	2.25	1.62	1.81	7.72	13.23	10.59	23.82	31.54	10.34	41.88	35.49	11.46	13.52	0.93
150	2.53	2.85	2.27	2.40	10.05	13.23	10.59	23.82	33.87	11.11	44.97	38.11	10.67	12.59	0.86
200	3.03	3.45	2.92	2.98	12.38	13.23	10.59	23.82	36.19	11.87	48.07	40.73	9.99	11.78	0.81
250	3.52	4.05	3.57	3.56	14.70	13.23	10.59	23.82	38.52	12.63	51.16	43.35	9.38	11.07	0.76
300	4.02	4.64	4.22	4.15	17.03	13.23	10.59	23.82	40.85	13.40	54.25	45.97	8.85	10.44	0.72
350	4.51	5.24	4.87	4.73	19.36	13.23	10.59	23.82	43.18	14.16	57.34	48.59	8.37	9.88	0.68
400	5.01	5.84	5.52	5.31	21.68	13.23	10.59	23.82	45.50	14.92	60.43	51.21	7.94	9.37	0.64
450	5.51	6.44	6.18	5.89	24.01	13.23	10.59	23.82	47.83	15.69	63.52	53.83	7.56	8.92	0.61
500	6.00	7.03	6.83	6.48	26.34	13.23	10.59	23.82	50.16	16.45	66.61	56.45	7.21	8.50	0.58
550	6,50	7,63	7,48	7,06	28,67	13,23	10,59	23,82	52,48	17,21	69,70	59,07	6,89	8,13	0,56

28.39 minutes to 45.92 minutes, and that of the Ecotrac at Pleternica from 38.79 minutes to 69.70 minutes.

The standard time is expressed by the time consumption per unit of product for the shown distances. The standard time of the Torpedo tractor at Kutjevo ranged from 23.94 min/m³ to 41.81 min/m³, that of the Torpedo at Pleternica from 26.46 min/m³ to 36.02 min/m³, that of the Ecotrac at Kutjevo from 25.35 min/m³ to 41.00 min/m³, and that of the Ecotrac at Pleternica from 32.99 min/m³ to 59.07 min/m³.

The number of cycles for a 480-minute working day ranged from 16.9 for the Ecotrac at Kutjevo, to 6.9 for the Ecotrac at Pleternica.

Figure 15. Standard times of the tractors
Slika 15. Norme vremena traktora

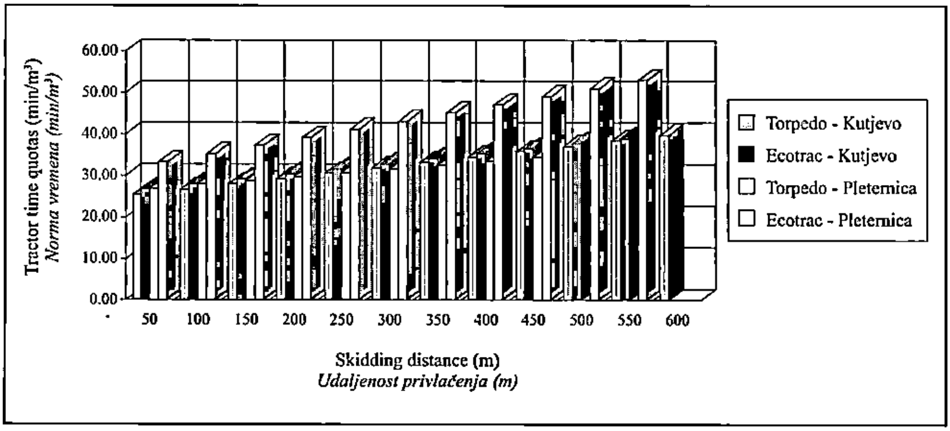
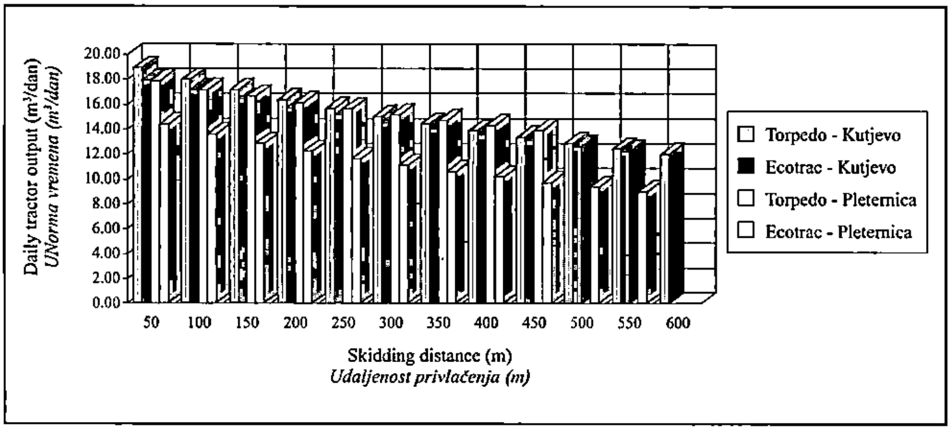


Figure 16. Daily output of the tractors
Slika 16. Dnevni učinci traktora



The daily output of the Torpedo tractor at Kutjevo ranged from 20.05 m^3/day to 11.48 m^3/day for distances of 50 to 600 m, that of the Torpedo at Pleternica from 11.48 m^3/day to 8.43 m^3/day for distances from 50 to 450 m, that of the Ecotrac at Kutjevo from 18.93 m^3/day to 11.71 m^3/day, and that of the Ecotrac at Pleternica from 14.60 m^3/day to 8.13 m^3/day for distances from 50 to 550 m.

STANDARD TIMES AND RELATIONSHIPS WITHIN THE TEAM
NORME VREMENA I ODNOSI U SKUPINI

Table 31 shows the standard times of the cutters (felling and processing) and those of the tractors, according to the variants for different skidding distances and their mutual relationships.

Since the standard time at inspection does not directly affect the standard time of the tractor, this relationship is not shown.

In the relationship between the standard times for felling and processing and the standard time of the Torpedo tractor (variant 1), it is evident that the tractor took 0.8 of the cutter's standard time for a distance of 50 m. For a distance of 100 to 200 m, it needed 0.7 of the cutter's standard time, while for 250 to 400m it took 0.6, and from 450 to 600 m it needed 0.5 of the cutter's standard time.

In the relationship between the standard time for processing and the standard time of a Torpedo tractor for a distance of 50 m, 0.6 of the cutter's standard time was taken. A distance ranging from 100 to 250 m took 0.5, and a distance from 300 to 600 m needed 0.4 of the cutter's standard time. In other words, at tractor skidding distances ranging from 100 to 600 m, one cutter could process the necessary quantity of wood to serve two tractors.

In variant 2, for a distance of 100 m, the Torpedo tractor needed 0.7 of the cutter's standard time, for distances ranging from 150 to 300 m it needed 0.6, for distances from 350 to 550 m it needed 0.5, and for 600 m it took 0.4 of the cutter's standard time. This means that, in variant 2, one cutter could serve two tractors only for distances starting from 350 m.

According to the data in Table 31 for the Ecotrac (Kutjevo) this relationship of standard times for variant 1 (felling + processing) amounted to 0.6 for distances ranging from 50 to 200 m, and 0.5 for distances from 250 to 450 m, and 0.4 for distances from 500 to 550 m. In variant 2, this relationship was disturbed only at the smallest distance of 50 m, but at larger distances this relationship was favourable and amounted to 0.5 up to distances of 250 m, and 0.4 for distances from 300 to 550 m.

According to the relationship between the processing standard time and the Ecotrac tractors, distances of 50 to 350 m took 0.4 of the cutter's standard time, while those ranging from 350 to 550 m took 0.3 of the cutter's standard time.

Table 32 shows the relationships between the standard time for felling and processing in variant 3 which amounted to 16.70 min/m^3 and the standard time of the Torpedo and Ecotrac tractors. The standard time of the Torpedo was significantly lower than that of the Ecotrac, so the relationship according to the time

Table 31. Relationship of the standard time of the cutter for variant 1 and 2 and that of the tractors, according to skidding distances at the Kutjevo work site

Tablica 31. Odnos norme vremena sjekača za inačicu 1 i 2 te traktora prema udaljenostima privlačenja na radilištu Kutjevo

Skidding distance *Udaljenost privlačenja*	Standard time *Norma vremena*			Tractor standard time *Norma vremena traktora*	Standard time ratio *Odnos norme vremena*		
	Variant 1 *Inačica 1*		Variant 2 *Inačica 2*		Variant 1 / Tractorstandard time *Inačica 1 / N.v. traktora*		Variant 2 / Tractor standard time *Inačica 2 / N.v. traktora*
	Felling + processing *Rušenje + izradba*	Processing *Izradba*	Cutting + processing *Sječa i izradba*		Felling + processing *Rušenje + izradba*	Processing *Izradba*	Cutting + processing *Sječa i izradba*
m / *m*	min/m^3 / *min/m^3*						
Torpedo - Kutjevo							
50	19.40	14.28	17.82	25.32	0.8	0.6	0.7
100	19.40	14.28	17.82	26.64	0.7	0.5	0.7
150	19.40	14.28	17.82 .	27.95	0.7	0.5	0.6
200	19.40	14.28	17.82	29.26	0.7	0.5	0.6
250	19.40	14.28	17.82	30.58	0.6	0.5	0.6
300	19.40	14.28	17.82	31.89	0.6	0.4	0.6
350	19.40	14.28	17.82	33.21	0.6	0.4	0.5
400	19.40	14.28	17.82	34.52	0.6	0.4	0.5
450	19.40	14.28	17.82	35.83	0.5	0.4	0.5
500	19.40	14.28	17.82	37.15	0.5	0.4	0.5
550	19.40	14.28	17.82	38.46	0.5	0.4	0.5
600	19.40	14.28	17.82	39.78	0.5	0.4	0.4
Ecotrac - Kutjevo							
50	16.93	11.81	14.78	26.72	0.6	0.4	0.6
100	16.93	11.81	14.78	27.96	0.6	0.4	0.5
150	16.93	11.81	14.78	29.19	0.6	0.4	0.5
200	16.93	11.81	14.78	30.43	0.6	0.4	0.5
250	16.93	11.81	14.78	31.66	0.5	0.4	0.5
300	16.93	11.81	14.78	32.89	0.5	0.4	0.4
350	16.93	11.81	14.78	34.13	0.5	0.3	0.4
400	16.93	11.81	14.78	35.36	0.5	0.3	0.4
450	16.93	11.81	14.78	36.60	0.5	0.3	0.4
500	16.93	11.81	14.78	37.83	0.4	0.3	0.4
550	16.93	11.81	14.78	39.06	0.4	0.3	0.4

consumed in felling and processing was from 0.1 to 0.2 larger. The Torpedo tractor for distances of up to 200 m needed 0.6 of the cutter's standard time, and for distances from 250 to 450 m took 0.5 of the cutter's standard time.

With the Ecotrac tractor, the relationship of standard times was similar to that on the previous work site. For distances up to 100 m, the relationship between the standard times was 0.5, for distances from 100 to 400 m it amounted to 0.4, and for distances ranging between 450 to 550 m it was 0.3. We can conclude from this that with average effort one cutter could serve two tractors for distances ranging from 50 m to 450 m, and for distances ranging from 450 to 550 m such a cutter could even serve three tractors.

Table 32. Relationship between the cutters' and the tractors' standard times, according to distances at the Pleternica work site

Tablica 32. Odnos norme vremena sjekača za inačicu 3 i traktora prema udaljenostima na radilištu Pleternica

Skidding distance *Udaljenost privlačenja*	Standard time Variant 3 *Norma vremena Inačica 3*	Tractor standard time *Norma vremena traktora*		Standard time ratio *Odnos norme vremena*	
				Variant 3 / Tractor time st. *Inačica 3/ N. v. traktora*	Variant 3 / Tractor time st. *Inačica 3/ N. v. traktora*
		Torpedo	Ecotrac	Torpedo	Ecotrac
m / *m*	min/m³ *min/m³*				
50	16.70	26.81	33.27	0.6	0.5
100	16.70	27.96	35.24	0.6	0.5
150	16.70	28.82	37.22	0.6	0.4
200	16.70	29.75	39.19	0.6	0.4
250	16.70	30.68	41.16	0.5	0.4
300	16.70	31.61	43.14	0.5	0.4
350	16.70	32.53	45.11	0.5	0.4
400	16.70	33.46	47.08	0.5	0.4
450	16.70	34.39	49.05	0.5	0.3
500	16.70	-	51.02	-	0.3
550	16.70	-	53.00	-	0.3

COSTS OF TEAMWORK
TROŠKOVI RADA SKUPINE

CALCULATIONS AND COSTS OF THE CUTTERS
KALKULACIJE I TROŠKOVI SJEKAČA

To calculate the costs for all three models of production, the planned calculations from 1995 of the public enterprise "Croatian Forests", Zagreb, were used. The calculation for a cutter in the cutting and inspection of wood was established on the basis of 200 working days a year. The calculations include the total reimbursement of costs to the workers, gross wages, and total compensations (contributions were 22.2% of gross wages), and others. In order to calculate the kuna value, the exchange rate of DEM1 = 3.7 kuna was used. The cost of one worker per day to the amount of 359.62 kuna, was reduced according to the new factor to 340.18 kuna.

Of this amount (359.62) the worker's share was 311.05 kuna, the share taken by the power saw amounted to 47.50 kuna, and additional tools accounted for 1.07 kuna.

CALCULATIONS AND COSTS OF TRACTORS
KALKULACIJE I TROŠKOVI TRAKTORA

As for the cutters, the calculations of the public enterprise "Croatian Forests", Zagreb, were also applied to the tractors, at the same exchange rate. The calculations consist of machine costs for the duration of 4 years, workers' costs, gross salaries and wage compensations in the process of production. These three points make up direct costs. General costs are allowance to direct costs at a rate of 45%, so, by including 5% profit to this calculation we can obtain the total cost of production, that is, total costs.

The daily cost of a Torpedo tractor amounted to 1,296.20 kn/day. By reducing this according to the current value of the German mark, we obtained the amount of 1,226.14 kn/day. Direct costs obtained in the same way amounted to 732.37 kn/day.

The daily cost of the Ecotrac tractor was 1,371.01 kn/day, or, in relation to the German mark, 1,296.90 kn, of which direct costs amounted to 764.84 kn.

PRODUCTION COSTS OF A WORKING TEAM
TROŠKOVI PROIZVODNJE RADNE SKUPINE

The costs of teamwork for three different models are shown in Tables 33 and 34. The standard time according to working operations and to variants was used in the calculation, as well as the daily output and the daily costs.

For model 1 in Table 33, the obtained figures are related to the figures for each individual worker. Cutter 1 (working alongside the Torpedo) took an average of 353.98 minutes a day, and cutter 2 (working alongside the Ecotrac) 354.98 minutes. A cutter took 301.44 minutes a day on average for inspection. The Torpedo tractor took an average of 400.59 min/day for an average distance of 254 m, and the Ecotrac 419.67 min/day for 238 m.

For model 2, the average achieved standard times of the current state of model 1 were applied, but for a 480-minute working day.

Model 3 relates to a 480-minute working day, and the formed standard times for all working operations.

Table 33. Daily output and costs of timber production of a team of workers at the Kutjevo work site

Tablica 33. Dnevni učinak i troškovi pridobivanja drva skupine radnika na radilištu Kutjevo

Working components *Radne sastavnice*			Work site Kutjevo *Radilište Kutjevo*					
			Model 1		Model 2		Model 3	
			Cutter 1 *Sjekač 1*	Cutter 2 *Sjekač 2*	Cutter 1 *Sjekač 1*	Cutter 2 *Sjekač 2*	Cutter 1 *Sjekač 1*	Cutter 2 *Sjekač 2*
Time standard, min/m³ *Norma vremena, min/m³*	Cutting and processing *Sječa i izradba*	Variant 1 *Inačica 1*	36.62	30.38	36.62	30.38	19.40	16.93
		Variant 2 *Inačica 2*	34.42	27.61	34.42	27.61	17.82	14.78
	Inspection *Preuzimanje*		19.33		19.33		10.40	
	Skidding *Privlačenje*	Torpedo	35.04		35.04		30.44	
		Ecotrac		42.05		42.05		31.61
Daily output, m³/day *Dnevni učinak, m³/dan*	Cutting and processing *Sječa i izradba*	Variant 1 *Inačica 1*	9.67	11.68	13.11	15.80	24.74	28.35
		Variant 2 *Inačica 2*	10.28	12.86	13.95	17.39	26.94	32.48
	Inspection *Preuzimanje*		15.59		24.83		46.15	
	Skidding *Privlačenje*	Torpedo	11.43		13.70		15.77	
		Ecotrac		9.98		11.41		15.18
Daily cost, kn/day *Dnevni trošak, kn/dan*	Cutting and processing *Sječa i izradba*	Variant 1 *Inačica 1*	340.18					
		Variant 2 *Inačica 2*	340.18					
	Inspection *Preuzimanje*		340.18					
	Skidding *Privlačenje*	Torpedo	1226.14				(723.37)*	
		Ecotrac	1296.9				(764.84)*	
Total cost per unit, kn/m³ *Ukupni trošak pojedini-ci, kn/m³*	Cutting and processing *Sječa i izradba*	Variant 1 *Inačica 1*	35.19	29.11	25.95	21.53	13.75	12.00
		Variant 2 *Inačica 2*	33.08	26.46	24.39	19.57	12.63	10.47
	Inspection *Preuzimanje*		21.82		13.70		7.37	
	Skidding *Privlačenje*	Torpedo	107.27		89.50		77.75	
		Ecotrac		129.95		113.66		85.43
	Total *Ukupno*	Variant 1 *Inačica 1*	164.29	180.88	129.15	148.89	98.87	104.80
		Variant 2 *Inačica 2*	162.17	178.23	127.59	146.93	97.75	103.28

Direct cost per unit, kn/m^3 *Direktni trošak pojedinici, kn/m^3*	Cutting and processing *Sječa i izradba*	Variant 1 *Inačica 1*	35.19	29.11	25.95	21.53	13.75	12.00
		Variant 2 *Inačica 2*	33.08	26.46	24.39	19.57	12.63	10.47
	Inspection *Preuzimanje*		21.82		13.70		7.37	
	Skidding *Privlačenje*	Torpedo	63.29		52.80		45.87	
		Ecotrac		77.33		67.03		50.38
	Total *Ukupno*	Variant 1 *Inačica 1*	120.30	128.27	92.45	102.26	66.99	69.75
		Variant 2 *Inačica 2*	118.19	125.61	90.89	100.30	65.87	68.23

* Direct tractor cost * *Direktni trošak traktora*

The standard time represents the average achieved standard time for the average working time of the cutter and the tractor.

The formed standard time represents a standard time that has been analytically processed. Effective time was statistically processed, and allowance time was studied by carrying out an analysis of each work interruption.

The standard times of 36.62 and 30.38 min/m^3 respectively for felling and processing in variant 1, models 1 and 2, for cutters 1 and 2, make up the total time consumed in felling trees and the total time consumed in the subsequent processing of the same trees (effective time and delay times).

In felling and processing variant 2, the standard times for models 1 and 2 amount to 34.42 min/m^3 and 27.61 min/m^3 respectively. Cutter 1 took 2.20 min/m^3, while cutter 2 took 2.77 min/m^3, that is, 6% and 9.1% less time than in variant 1.

The formed standard time of variant 1 in model 3 is lower than the average standard time by 17.22 min/m^3, or 47.0%, for cutter 1, and by 12.83 min/m^3, or 46.5%, for cutter 2 in model 1.

The standard time of inspection at the auxiliary landing in models 1 and 2 amounts to 19.33 min/m^3, and the formed standard time in model 3 amounts to 10.40 min/m^3, that is, 46.2% lower.

The standard times of the tractors were obtained according to the average achieved skidding distances for models 1 and 2 (254 m and 238 m), whereas a skidding distance of 250 m was taken in model 3. In models 1 and 2 the average achieved standard times were applied, and in model 3 the formed standard times were used.

The achieved daily output in variant 2, model 2, was 26.3% higher (cutter 1) and 26.0% higher (cutter 2) than in model 1, and 2.6 and 2.5 times higher in model 3 when compared with model 1.

The achieved daily output at inspection was 1.6 times higher in model 2, and 3.0 times higher in model 3 than in model 1.

The obtained daily output of the Torpedo tractor in model 2 amounted to 13.70 m^3/day, and that of the Ecotrac tractor 11.41 m^3/day, which was 16.6% and 12.5% higher than in model 1.

The daily output of the Torpedo tractor in model 3 amounted to 15.77 m^3/day and that of the Ecotrac tractor 15.18 m^3/day, which was 27.2% and 34.2% higher than in model 1, and 12.7% and 24.7% higher than in model 2.

The cost of felling and processing in model 1 was the lowest for cutter 2, variant 2, amounting to 26.46 kn/m^3, and was the highest for cutter 1, variant 1, amounting to 35.19 kn/m^3.

The cost of felling and processing in model 2 was the lowest for cutter 2, variant 2, amounting to 19.57 kn/m^3, and the highest for cutter 1, variant 1, amounting to 25.95 kn/m^3.

The cost of felling and processing in model 3 was the lowest for cutter 2, variant 2, amounting to 10.47 kn/m^3, and the highest for cutter 1, variant 1, amounting to 13.75 kn/m^3.

The cost of cutter 2 and cutter 1 in model 2 was 26.0% and 26.3% lower respectively in relation to model 1. In model 3 in relation to model 1, it was 2.5 and 2.6 times lower, while in model 2, it was 1.9 times lower in relation to model 1 for both cutters.

The cost of inspection in model 1 amounted to 21.82 kn/m^3, and in model 2 it amounted to 13.70 kn/m^3, or 37.2 % less. In model 3, it amounted to 7.37 kn/m^3, being 3 times lower than in model 1, and 1.9 times lower than in model 2.

The Torpedo tractor in model 1, for an average skidding distance of 254 m, had a total cost of 107.27 kn/m^3, while the Ecotrac, for an average skidding distance of 238 m, had a cost of 129.95 kn/m^3.

In model 2, the cost of the Torpedo tractor amounted to 89.50 kn/m^3 which was 16.6% lower in relation to model 1, while the cost of the Ecotrac amounted to 113.66 kn/m^3, which was 12.5% lower than in model 1.

In model 3, the cost of the Torpedo for a skidding distance of 250 m amounted to 77.75 kn/m^3, which was 27.5% lower in relation to model 1, and 13.1% lower in relation to model 2. In model 3, the cost of the Ecotrac for a skidding distance of 250 m amounted to 85.43 kn/m^3, and was 34.3% lower in relation to model 1, and 24.8% lower in relation to model 2.

The total cost of one unit of production (felling and processing, inspection and skidding) in model 1 for the first pair (cutter and Torpedo tractor) amounted to 164.29 kn/m^3 in variant 1, and 162.17 kn/m^3 in variant 2.

The second pair (cutter and Ecotrac tractor) in model 1 represented a total cost of 180.88 kn/m^3 in variant 1, and 178.23 kn/m^3 in variant 2, which was 9.2% higher than the first pair in variant 1, and 9.0% higher in variant 2.

In model 2, the total cost of the first pair in variant 1 amounted to 129.15 kn/m^3, and that of the second pair 148.89 kn/m^3, which was 21.4% and 17.7% lower than in model 1.

In model 2, the total cost of the first pair in variant 2 amounted to 127.59 kn/m^3, and that of the second pair 146.93 kn/m^3, which was 21.3% and 17.6% lower respectively than in model 1.

In model 3, the total cost of the first pair in variant 1 amounted to 98.87 kn/m³, and that of the second pair 104.80 kn/m³, which was 39.8% and 42.1% lower respectively than in model 1, and 23.4% and 29.7% lower than in model 2.

In model 3, the total cost of the first pair in variant 2 amounted to 97.75 kn/m³, and that of the second pair 103.28 kn/m³, which was 39.7% and 42.1% lower than in model 1, and 23.4% and 29.7% lower than in model 2.

The direct costs in model 1 were the lowest for the first pair in variant 2, amounting to 118.19 kn/m³, and the highest for the second pair in variant 1, amounting to 128.27 kn/m³. In model 2, for the same pair and the same variant, the cost was 90.89 kn/m³ and 102.26 kn/m³ respectively, and in model 3 it amounted to 65.87 and 69.75 kn/m³ respectively.

The direct costs of the first pair in variant 2 model 3 were 44.3% lower, and those of the second pair, variant 1, were 45.6% lower compared with model 1, while compared with model 2 the direct costs were 27.5% lower for the first pair and 31.8% lower for the second pair.

Table 34 shows the standard times, the daily output and the total and direct costs per m³ for models 1, 2 and 3 at the Pleternica work site. All three models were processed identically at both work sites.

A cutter spent a daily average of 423.35 minutes on felling and processing, and a worker (cutter) 423.45 minutes on inspection. The Torpedo tractor spent a daily average of 425.42 minutes at the work site, and the Ecotrac 427.34 minutes.

The standard time for felling and processing in models 1 and 2 for variant 3 amounted to 24.49 min/m³, and the formed standard time in model 3, variant 3, amounted to 16.70 min/m³, which was 31.8% lower than in models 1 and 2.

The standard time of variant 3 at Pleternica was 12.13 min/m³ less than the highest standard time achieved at Kutjevo in model 1 for the first cutter in variant 1. This standard time at Pleternica therefore amounted to 33.1% of the highest standard time at Kutjevo. It was also 3.12 min/m³ or 11.3% lower than the lowest standard time of the second cutter in variant 2.

The standard time for inspection amounted to 24.11 min/m³ in models 1 and 2, and 9.34 min/m³ in model 3, which was 2.6 times lower.

The standard time of the Torpedo tractor for models 1 and 2 amounted to 43.22 min/m³ for an average achieved skidding distance of 326 m, while the standard time of the Ecotrac tractor amounted to 61.82 min/m³ for an average distance of 344 m. In model 3, the average skidding distance of 350 m was taken for both tractors in order to determine the formed standard time.

The daily output of variant 3 in model 1 amounted to 17.29 m³/day, and in model 2 to 19.60 m³/day, which was 11.8% higher. In model 3, the daily output amounted to 28.74 m³/day, or was 39.8% higher than in model 1. The daily output of model 3 was 31.8% higher than that of model 2.

The daily output of inspection in model 1 amounted to 17.56 m³/day, and in model 2 it reached 19.91 m³/day, which was 11.8% higher, while in model 3 it

Table 34. Daily output and costs of timber logging of a team of workers at the Pleternica work site

Tablica 34. Dnevni učinak i troškovi pridobivanja drva skupine radnika na radilištu Pleternica

Working components *Radne sastavnice*			Working site Pleternica *Radilište Pleternica*		
			Model 1	Model 2	Model 3
Time standard, min/m^3 *Norma vremena min/m^3*	Cutting and processing *Sječa i izradba*	Variant 3 *Inačica 3*	24.49	24.49	16.70
	Inspection *Preuzimanje*		24.11	24.11	9.34
	Skidding *Privlačenje*	Torpedo	43.22	43.22	32.11
		Ecotrac	61.82	61.82	45.11
Daily output. m^3/day *Dnevni učinak m^3/dan*	Cutting and processing *Sječa i izradba*	Variant 3 *Inačica 3*	17.29	19.60	28.74
	Inspection *Preuzimanje*		17.56	19.91	51.39
	Skidding *Privlačenje*	Torpedo	9.84	11.11	14.95
		Ecotrac	6.91	7.76	10.64
Daily cost, kn/day *Dnevni trošak kn/dan*	Cutting and processing *Sječa i izradba*	Variant 3 *Inačica 3*		340.18	
	Inspection *Preuzimanje*			340.18	
	Skidding *Privlačenje*	Torpedo		1226.14	(723.37)*
		Ecotrac		1296.9	(764.84)*
Total cost per unit, kn/m^3 *Ukupni trošak po jedinici kn/m^3*	Cutting and processing *Sječa i izradba*	Variant 3 *Inačica 3*	19.37	17.36	11.84
	Inspection *Preuzimanje*		19.37	17.09	6.62
	Skidding *Privlačenje*	Torpedo	124.61	110.40	82.02
		Ecotrac	187.68	167.03	121.88
	Total *Ukupno*	Torpedo	163.35	144.85	100.48
		Ecotrac	226.43	201.47	140.34
Direct cost per unit, kn/m^3 *Direktni trošak po jedinici kn/m^3*	Cutting and processing *Sječa i izradba*	Variant 3 *Inačica 3*	19.37	17.36	11.84
	Inspection *Preuzimanje*		19.37	17.09	6.52
	Skidding *Privlačenje*	Torpedo	73.51	65.13	48.39
		Ecotrac	110.69	98.51	71.88
	Total *Ukupno*	Torpedo	112.26	99.58	66.75
		Ecotrac	149.43	132.95	90.23

* Direct tractor cost   * *Direktni trošak traktora*

amounted to 51.39 m³/day, and was 2.9 times higher in relation to model 1, and 2.6 times higher in relation to model 2.

The daily output of the Torpedo tractor in model 1 amounted to 9.84 m³/day, and in model 2 it reached 11.11 m³/day, which was 11.4% higher. In model 3, it amounted to 14.25 m³/day, and was 30.9% higher in relation to model 1, and 22.0% in relation to model 2.

In model 1, the Ecotrac tractor achieved a daily output of 6.91 m³/day. In model 2, this performance was 7.76 m³/day, or 11.0% higher. In model 3, it amounted to 9.88m³/day, and was 30.1% higher than in model 1, and 21.5% higher than in model 2.

The costs of cutting and processing in variant 3, model 1, amounted to19.37 kn/m³. In model 3, the costs amounted to 17.36 kn/m³, and were 10.4% lower than in model 1, while in model 3 they amounted to 11.84 kn/m³ or 38.9% of model 1.

The cost of inspection in model 1 was equal to the cost of cutting and processing, while in model 2 this cost differed slightly. In model 3, it amounted to 6.62 kn/m³, which was 44.1% lower than the cost of cutting and processing.

The cost of the Torpedo tractor in model 1 amounted to 124.61 kn/m³. In model 2, it amounted to 110.40 kn/m³, or was 11.4% lower. In model 3, the cost amounted to 86.03 kn/m³ and was 31% lower than in model 1, and 22.1% lower than in model 2.

The Ecotrac tractor in model 1 achieved a cost of 187.68 kn/m³. In model 2, the cost was 167.03 kn/m³, or 11.0% lower. In model 3, the cost was 131.28 kn/m³, or 30.1% lower than in model 1, and 21.4% lower than in model 2.

The total cost of one unit of production with the Torpedo tractor in model 1 amounted to 163.35 kn/m³, and with the Ecotrac it reached 226.43 kn/m³, or was 27.9% higher. In model 2, the costs with the Ecotrac tractor were 28.1% higher, and in model 3 they were 30.2% higher than the total costs with the Torpedo tractor.

The cost with the TP in model 2 was 11.3% lower, and in model 3, 38.5% lower than in model 1. The cost with the Ecotract tractor was 11.0% lower in model 2, and 38.0% lower in model 3 than in model 1.

The total direct costs with a Torpedo tractor were 0.88 kn/m³ higher in model 3 than at the other work site with cutter 1, in variant 2, although the average skidding distance was 100 m greater. With the Ecotrac, these costs amounted to 22.0 kn/m³, which were 24.4% higher.

CONCLUSION
ZAKLJUČAK

Research was conducted on teamwork in the felling, processing, skidding and inspection of wood. The productivity was studied of two teams, the first made up of five, and the second of four workers. The work took place in thinning stands on approximately equal terrain and stand conditions.

At Kutjevo, work was carried out in two different ways, or in two variants. In variant 1, the felling was done before the vegetation period and before the engagement of the entire team. In the second case (variant 2), the trees were felled, and immediately processed into assortments which were then skidded and delivered to the auxiliary landing.

At the Pleternica work site, all the jobs were done simultaneously: felling and processing, bucking and timber inspection at the stump, and immediately after that, skidding by tractors to the auxiliary landing

The mean volume of the load of the TP tractor amounted to 1.58 m^3, that of the EP was 1.18 m^3, that of the TK was 1.20 m^3, while the smallest mean volume was that of the EK, which amounted to 1.12 m^3. The difference between the largest and smallest mean load volume was 29.1%. The mean volume of one piece in the load of the EK tractor was 0.151m^3, that of the TK tractor was 0.149 m^3, followed by that of the TP with 0.142 m^3, and that of the EP with 0.140 m^3.

A time analysis was made for felling, processing, timber inspection and skidding of wood at both work sites and for all three variants. The time study was carried out by using the repetitive chronometer method.

The effective time of the cutter working alongside the TK (cutter 1), variant 2, amounted to 35.95% of total time, and the effective time of the cutter alongside the EK (cutter 2) came to 42.93% of total time. Delay time amounted to 64.05% and 57.07% respectively. At the Pleternica work site, the effective time of a cutter amounted to 41.53% of total time, while delay time amounted to 58.47% of total time.

The allowance time of a cutter alongside a TK amounted to 73.7% of effective time, the allowance time of a cutter alongside an EK came to 60.3% of effective time, and at the Pleternica work site allowance time amounted to 64.2% of effective time. Such high allowance time for the cutter was a consequence of the small proportion of effective time in the working day. To obtain the optimal engagement of one cutter, two tractors would be necessary for skidding.

To inspect the wood assortments at the auxiliary landing at Kutjevo, effective time was 20.69% of total time. At the Pleternica work site, it amounted to 21.40% of total time. The average effective time for inspection at the auxiliary landing amounted to 6.21 min/m^3, and at the felling site it came to 5.16 min/m^3.

The allowance time of the cutter for the inspection of wood assortments at the auxiliary landing amounted to 67.35%, and at the felling site to 78.23%, which was 10.88% more. In order to increase the engagement of the timber inspectors, a larger number of tractors would be necessary for skidding timber, because in this way, waiting time would be turned into effective time.

When analysing the time of one cycle, equal distances were taken for all tractors: 300 m along the skid trail and the felling site, and 100 m along the auxiliary landing. The total time of a cycle was the lowest for the EK tractor, amounting to 32.38 minutes, and the highest total time was for the TP, amounting to 45.56 minutes, which was 13.18 minutes or 28.9% more. The total time of a cycle for the TK amounted to 33.18 minutes, while that of the EP came to 42.53 minutes.

In the structure of the total time of a cycle, effective time ranged from 75.3% for the EP to 80.9% for the TK. The share of work at the felling site for the EP was the smallest and amounted to 41.1%, while the EK had the largest share, which was 59.4% of effective time. When working at the auxiliary landing (unloading), the lowest effective time was that of the EK tractor (18.6%) and the highest was achieved by the EP tractor (1.8%).

The standard time for a skidding distance of 400 m was the lowest for the TP tractor, amounting to 34.85 min/m³. When compared with the standard time of the TP, the time standard of the TK was 0.46 min/m³ higher, and for the EK it was 1.46 min/m³ higher, while the greatest difference of 16.36 min/m³ was achieved by the EP. The volume of the load and the personality of the tractor driver had a significant impact on the time consumption of a loaded and unloaded tractor.

The work of cutters 1 and 2 in binding the load at Kutjevo amounted to 27.8% and 17.5% of the effective time of the tractor. For the same operation, the tractor driver took 11.9% and 15.0% of effective time. At Pleternica, the time relations were different for binding the load. The cutter and the inspector took 1.5% and 1.8% of effective time, and the tractor drivers took 22.4 and 23.3% of effective tractor time respectively.

The speeds of the unloaded tractors were generally lower along the skid trail and the felling site than at the auxiliary landing. Only the EP achieved a lower speed at the auxiliary landing. Its speed here was 0.39 km/h lower. The other average speeds of the unloaded tractors at the auxiliary landing ranged from 7.50 to 9.86 km/h, and along the skid trail and the felling site the average speeds ranged from 4.09 to 5.97 km/h.

The lowest average speed of a loaded tractor along the skid trail and the felling site was 3.48 km/h, and the highest average speed reached 5.82 km/h. At the auxiliary landing, loaded tractors achieved speeds ranging from 3.54 km/h to 5.59 km/h.

The effective time of a team of five workers at Kutjevo amounted to 683.09 min/day, or 66.7% of total time. Allowance time amounted to 341.38 min/day, or 33.3% of total team time. The effective working time of a cutter and a tractor amounted to 620.71 min/day, or 60.6% of total time, that is, 90.9% of effective team time.

In the 4-worker team at Pleternica, one cutter and two tractors achieved an effective time of 547.01 min/day, or 58.8% of total time, or 85.8 % of effective team time. The total time of the cutters and tractors amounted to 769.44 min/day, or 82.7% of total team time. The effective time of the team at the Pleternica work site amounted to 637.62 min/day, or 68.5% of total time, and allowance time came to 293.32 min/day, or 31.5% of total team time.

The total time of the Kutjevo team amounted to 1,024.47 min/day, or 42.7% of regulated working time, and that of the Pleternica team amounted to 930 min/day, or 48.5% of regulated working time.

The standard time for a skidding distance of 50 m with the TK amounted to 23.94 min/m³. With the EK, it was 1.41 min/m³ higher, with the TP it was 2.52 min/m³ higher, and with the EP it came to 8.94 min/m³ higher. For a skidding distance of 300 m, the differences were significant. Therefore, with the EP tractors, the difference was 13.91 min/m³ compared with the time of the TK tractor for the same distance.

The daily output of the TK ranged from 20.05 m³/day to 11.48 m³/day for distances of 50 to 600 m. The daily output of the TP ranged from 18.14 m³/day to 13.32 m³/day for skidding distances between 50 and 450 m. The daily output of the EK ranged from 18.93 m³/day to 11.71 m³/day for distances of 50 to 550 m, while the daily output of the EP, for the same distances, ranged from 14.60 m³/day to 8.13 m³/day.

The relations of the standard times for felling and processing according to the variants and the tractor standard times show that the burden was not balanced within the team. Within the range of skidding distances of 450 to 600 m, with the TK (variant 1), the relation between the cutter's standard time and that of the tractor was 0.5:1. This shows that for these skidding distances one cutter would be sufficient to serve two tractors. For smaller skidding distances, the ratio was from 0.6:1 to 0.8:1.

With the same tractor and in variant 1, the ratio of the standard time for processing and the standard time of skidding for skidding distances between 50 to 600 m ranged from 0.4:1 to 0.6:1. In variant 2, for distances of 50 to 600 m, the standard time ratio for the TK was from 0.4:1 to 0.7:1.

At the same work site, with the Ecotrac tractor, the relation of the standard time for felling and processing (separately) in variant 1 and the standard time for skidding, for distances ranging from 50 to 550 m, ranged from 0.4:1 to 0.6:1. For the same tractor and variant 1, the ratio of the processing standard time and the skidding standard time, for distances ranging from 50 to 550 m, was from 0.3:1 to 0.4:1. In variant 2, and for the same distances, the ratio was from 0.4:1 to 0.6:1.

At the Pleternica work site, the ratio of felling and processing standard times in variant 3, and the skidding standard time of the Torpedo tractor for skidding distances ranging from 50 to 450 m, was from 0.5:1 to 0.6:1, and that of the Ecotrac tractor, for distances ranging from 50 to 550 m, was from 0.3:1 to 0.5:1.

Costs were considered according to the variants, cost models and cutters. The direct cost of model 1 of the Kutjevo team was the lowest for cutter 1, variant 2, and amounted to 118.19 kn/m³, and the highest for cutter 2, variant 1, and amounted to 128.27 kn/m³. In model 2, the lowest cost, 90.89 kn/m³, was achieved by cutter 1 in variant 2, and the highest cost, 102.26 kn/m³, was that of cutter 2 in variant 1. The direct costs for cutter 1 in model 3, variant 1, amounted to 66.99 kn/m³, and in variant 2 they were 65.87 kn/m³.

The direct costs of the Pleternica team with the TP in model 2 were 11.3% lower, and in model 3, 38.5% lower than in model 1. The costs with the Ecotract were 11.0% lower in model 2 and 38.0% lower in model 3 when compared with model 1. The direct costs of the Pleternica team with the Torpedo tractor were 0.88 kn/m³ higher in model 3 than at the Kutjevo work site for cutter 1 in variant 2, although the average skidding distance was 100 m greater. With the Ecotrac, these costs were 22.0 kn/m³, or 24.4%, higher.

Teamwork has been accepted in Croatian forestry and has brought about an improvement in production. However, this study on teamwork shows that imperfections exist in team organisation and indicates that there is a need for its optimisation. The factors studied in this work are the basis for improvements to be made in teamwork, in which working time will be better exploited and machines will be more effective, at the same time incurring lower costs. Only with such optimally organised teamwork will the advantages of teamwork over traditional work become fully evident.

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SKUPNI RAD PRI PROREDAMA U SASTOJINAMA POŽEŠKOGA GORJA S POSEBNIM OSVRTOM NA PRIVLAČENJE DRVA TRAKTORIMA

SAŽETAK

Klasični način rada pri eksploataciji šuma traje predugo jer su faze rada vremenski odvojene. Od sječe i izradbe pa do otpreme proizvoda proticalo je više mjeseci. Troškovi eksploatacije šuma uz stanje tržišta, odnosno ponudu i potražnju određene vrste drva i drvnih sortimenata zahtijevali su poboljšane metode rada u eksploataciji šuma. Rješenje za povećenje proizvodnosti treba tražiti u boljoj organizaciji rada i boljem iskorištavanju radnoga vremena. Jedan pokušaj boljega oblikovanja rada pri eksploataciji šuma bio je uvođenje skupnoga rada.

Prema broju izvođača u proizvodnom procesu razlikuje se pojedinačni i skupni rad. Skupni je rad definiran kao rad skupine ljudi u istom vremenu, na istom prostoru i na istom proizvodnom zadatku. Takav se rad odvija u jednostavnoj ili složenoj suradnji i značajan je za sve razvijene oblike proizvodnje.

Radna je skupina usklađena skupina radnika koja se oblikuje zato da bi kao samostalna jedinica s potrebnim radnim sredstvima obavila radni nalog. Bit je skupnoga rada u boljem povezivanju i izvođenju svih postupaka, od pripreme rada do otpreme šumskih sortimenata kupcu.

Cilj je ovoga istraživanja proučavanje primjene skupnoga rada pri sječi, izradbi, privlačenju i preuzimanju drva u prorednim sastojinama požeškoga gorja. Proučavane su dvije skupine radnika i njihovi ostvaraji u odnosu na tri načina organizacije rada.

Provedbom studija rada i vremena utvrdit će se proizvodnost skupine te norme vremena i norme učinka. Također će se istraživati troškovi za tri različita modela na dvama radilištima, i to pojedinačno za svakoga člana i ukupno za skupinu radnika.

Terenska su istraživanja provedena na području Uprave šuma Požega, koja zauzima 49 486,11 ha, s ukupnom drvnom zalihom od 9 001 835 m^3 te prosječnim godišnjim prirastom od 310 072 m^3 i prosječnim etatom od 204 194 m^3.

Efektivno vrijeme skupine u Kutjevu iznosi 683,09 min/dan ili 66,7 % od ukupnoga vremena. Dodatno vrijeme iznosi 341,38 min/dan ili 33,3 % ukupnoga vremena skupine. Vrijeme sječe i izradbe obojice sjekača iznosi 164,06 min/dan ili 16,0 %, a dodatno vrijeme 185,65 min/dan ili 18,1 % ukupnoga vremena skupine.

Utrošak vremena za obojicu sjekača na vezanju tovara traktora iznosi 111,24 min/dan ili 10,9 % ukupnoga vremena skupine.

Na radilištu u Pleternici jedan sjekač i dva traktora ostvarili su efektivno vrijeme u iznosu od 547,01 min/dan ili 58,8 % od ukupnoga, odnosno 85,8 % od efektivnoga vremena skupine. Dodatno vrijeme iznosi 222,43 min/dan ili 23,9 % od ukupnoga vremena.

Norma vremena za traktor Torpedo u Kutjevu se kreće od 23,94 min/m^3 do 41,81 min/m^3, za Torpedo u Pleternici od 26,46 min/m^3 do 36,02 min/m^3, a Ecotraca u Kutjevu od 25,35 min/m^3 do 41,00 min/m^3 te Ecotraca u Pleternici od 32,88 min/m^3 do 59,07 min/m^3.

Dnevni učinak traktora Torpedo u Kutjevu kreće se od 20,05 m^3/dan do 11,48 m^3/dan pri udaljenostima 50 m do 600 m, Torpeda u Pleternici od 11,48 m^3/dan do 8,43 m^3/dan pri udaljenostima 50 m do 450 m, a Ecotraca u Kutjevu od 18,93 m^3/dan do 11,71 m^3/dan te Ecotraca u Pleternici od 14,60 m^3/dan do 8,13 m^3/dan za udaljenost od 50 m do 550 m.

U modelu 3 ukupni trošak prvoga para na radilištu u Kutjevu za inačicu 2 iznosi 97,75 kn/m^3, a drugoga para 103,28 kn/m^3 te je 39,7 %, odnosno 42,1 % manji u odnosu na model 1 i 23,4 %, odnosno 29,7 % u odnosu na model 2.

Ukupan trošak proizvodnje jedinice proizvoda na radilištu u Pleternici uz traktor Torpedo u modelu 1 iznosi 163,35 kn/m^3, a uz Ecotrac 226,43 kn/m^3 ili 27,9 % više. U modelu 2 troškovi uz Ecotrac veći su 28,1 %, a u modelu 3 za 30,2 % od ukupnih troškova uz Torpedo.

Skupni je rad prihvaćen u hrvatskom šumarstvu i donio je napredak u proizvodnosti. Ova su istraživanja skupnoga rada upozorila na nesavršenost organizacije skupine i potrebe njihove optimizacije. Čimbenici proučavani u ovome radu osnova su takve optimizacije pri kojoj će se bolje iskorištavati radno vrijeme, strojevi raditi svrhovitije i uz niže troškove. Tek takvim optimalnim postavljanjem skupnoga rada njegove prednosti pred klasičnim radom doći će do punoga izražaja.

Ključne riječi: skupni rad, sječa, izrada, privlačenje, kontrola, standardno vrijeme, dnevni učinak, troškovi

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FOREST VEGETATION IN THE CITY OF ZAGREB AND THE ZAGREB COUNTY

ŠUMSKA VEGETACIJA GRADA ZAGREBA I ZAGREBAČKE ŽUPANIJE

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The paper presents the results of phytocoenological research into the forests of the City of Zagreb and the Zagreb County. These forests take up approximately 143,000 ha. The forest vegetation occurs in various climatic, pedological and other conditions at altitudes ranging from 120 to 1,033 m. For this reason, there are about twenty more or less distinctive forest associations, of which ten are accompanied with phytocoenological tables and presented in more detail. A well-known method of research and presentation devised by the Zurich-Montpellier Phytocoenological School has been used. The result of the research is the forest vegetation map of the studied area on a scale 1:100,000, of which only two characteristic fragments giving an approximate cross-section of the lowlands and the region of lower and higher hills is given for technical reasons.

Key words: forest vegetation, floral composition, the City of Zagreb and the Zagreb County

INTRODUCTION
UVOD

The City of Zagreb and the Zagreb County are located in the most densely populated region in the west of Croatia. Although this region was settled very early and developed a relatively rapid and significant industrial, infrastructural and other features, the forests in the studied area cover over 143,000 ha or almost 40%. They have largely retained their natural composition and structure and are very suitable for phytocoenological research. This area is a very good example of vertical zoning of the forest vegetation in the south-west of the Pannonian plain with many pre-Alpine floral-genetic properties continuing into neighbouring Slovenia. The altitudinal difference between the studied forest communities is slightly less than one thousand meters, which contributes to the wealth and diversity of the floral composition of these associations.

Forest vegetation is presented in altitudinal belts. In the lowland belt from 80 to 150 meters above sea level, the Rivers Sava, Lonja, Česma, Kupa and a number of smaller, largely ameliorated watercourses are responsible for the basic features of the geological-lithological and pedological structure and for the vegetational picture. The belt of low hills between 150 and 400 (500) meters, the belt of higher hills from 400 to 800 meters and the mountain belt above 800 meters have very different pedological and climatic conditions. For this reason, the phytocoenological composition displays clear vertical zoning in which the principal species are sessile oak, followed by common beech in the belt of higher hills and beech and fir in the mountainous belt. Different lithological substrates condition a large number of forest associations belonging to various syntaxonomic categories. The twenty basic forest associations are classified into seven alliances, three orders and two classes, which is partly shown in four phytocoenological tables.

The forest vegetation of the City of Zagreb and the Zagreb County has been studied for the past four years. In the course of the research, phytocoenological literature of other authors has been drawn upon, first of all of Anić (1940), Baričević (1998), Cestar *et at.* (1978-1982), Glavač (1958 and 1959), Rauš (1969 and 1996), Rauš *et al.* (1992), Rauš & Vukelić (1993), Šegulja (1974), Šugar (1972), and Vukelić (1991). The survey is accompanied with a printed phytocoenological map on a scale 1:100.000 with 13 most important phytocoenoses. Some associations occur in fragments over very small areas (various riparian associations, broadleaved forests of good quality) or they mix intensively due to well-developed terrain orography and changes in synecological conditions. For this reason they cannot be determined and shown accurately on the 1:100.000 scale.

A DESCRIPTION OF FOREST ASSOCIATIONS
OPIS ŠUMSKIH ZAJEDNICA

THE LOWLAND (PLANAR) VEGETATION BELT
NIZINSKI (PLANARNI) POJAS

The lowland or planar vegetation belt, extending between 80 and 150 meters above sea level, accounts for half of the forest vegetation in the studied area. It represents the initial level of the vertical occurrence of forest vegetation in this area and is characterised primarily by forests of pedunculate oak, narrow-leaved ash, black alder, willows and poplars. Their origin and survival is more or less linked to surface water and groundwater. In terms of orography, the localities where these species and forest associations occur are the plains between rivers, with alternations of bogs, micro-depressions, depressions, wide humid terraces, non-differentiated micro-elevations and drained and fresh micro-elevations. The soils are hydromorphous and are still developing depending on the time of origin and degree of moisture. However, the most common are mineral-swampy and gleyic soils and lowland pseudogley on elevations. The macroclimate of the area is continental with a mean annual temperature of 9°C and the precipitation quantity of 1,000 mm.

The decisive ecological factor for the growth and development of the forest vegetation of the planar belt is water, whether in the form of floodwater, (poplar and willow forests), groundwater (forests of pedunculate oak), or both kinds of water (forests dominated by black alders and narrow-leaved ashes).

The forest vegetation of the planar belt in Croatia is characterised by relatively well preserved forest complexes, very valuable forests of pedunculate oak, the occurrence of narrow-leaved ash and very distinctive biological diversity. However, these characteristics are more prominent in Central Posavina and East Croatia than in the studied area.

The phytocoenological picture of the forests in the lowland vegetation belt is complex, consisting of riparian forests along riverbeds, forests in bogs and micro-depressions and forests on micro-elevations.

Riparian forests along riverbeds and bogs
Ritske šume uz riječna korita i bare

These forests belong to the alliance of riparian forests *Salicion albae.* They occur along the river Sava, Kupa, Česma, Lonja and their tributaries. However, they are arranged in very narrow and mosaic-like fragments because the riverbanks - the potential sites of these associations - have been regulated with dams. More significant complexes are found along the river Sava.

Proper riparian forests are those forests that extend along rivers, are regularly flooded with periodical floods, display distinct syndynamic relations and grow on intensively developing soils. Forest associations are paraclimatic, and the degree of soil development, the occurrence of willow shrubs, the formation of plant communities and other structural relationships are dependent on the frequency, height and duration of floods. The basic forest species in riparian forests participating in almost all succession stages are: *Salix triandra, Salix purpurea, Salix alba, Populus alba, Populus nigra, Ulmus laevis, Fraxinus angustifolia* and *Quercus robur*. Three associations have been identified in the studied area:

The shrub of purple willow (*Salicetum purpureae* Wend. - Zel. 1952) is a frequent, fragmentarily distributed association on the islands and banks of large rivers, but also of smaller, economically insignificant streams. It has a transitional character and forms a border forest association towards swampy phytocoenoses, primarily reeds. The soils of the association are shallow and undeveloped, but well supplied with nutrients due to matter sedimentation.

Salix purpurea dominates in the first, upper layer of several meters, while the very dense lower layer of ground vegetation consists of *Rubus caesius, Ranunculus repens, Euphorbia salicifolia, Iris pseudacorus, Solanum dulcamara, Polygonum lapatifolium* and other species.

The forest of white willow with bedstraw (*Galio-Salicetum albae* Rauš 1973) is developed in micro-depressions on alluvial carbonates, undeveloped soils along bogs and large water areas, continuing onto the purple willow association or directly onto reeds or marshy phytocoenoses. Floods are common in this association, and this is the reason why willows form adventitious roots from the stem. When the water retreats, the roots remain hanging, giving the forest a peculiar appearance. Such old trees can be found along the rivers Lonja and Česma.

The most important element in the floral composition of the association is white willow, while the ground layer consists of *Galium palustre, Carex elata, Iris pseudacorus, Agrostis alba, Rubus caesius, Lysimachia nummularia, Lysimachia vulgaris, Ranunculus repens, Lythrum salicaria, Bidens tripartita* and others.

It should be mentioned that the former large areas of this phytocoenosis have been meliorated and either covered with cultures of hybrid poplars or turned into agricultural areas.

The forest of white willow and black poplar (*Salici albae-Populetum nigrae* Tx. 1931) is a mixed association with the principal edifying species being the white willow and black poplar. It is especially developed in Croatian Podunavlje, but fragments can also be found along the river Sava from Podsused to Sisak. The building of dams and ameliorative operations have caused this forest to lose its natural appearance and structure, and classical floods and synecological conditions, such as those occurring on the Danube islands, are absent. There, the floods are rarer and last for shorter periods than the floods in the forest of white willow and bedstraw, but are more copious and distinct than on the higher positions taken up by the stands of black and white poplars.

Salix alba and *Populus nigra* participate equally in the tree layer, while in the shrub and ground layer, apart from the species of the flooded sites from the alliance *Salicion albae*, there are plants of less humid sites, such as *Circaea lutetiana, Carex remota, Scrophularia elata* and *Lycopus europaeus*.

A particularly interesting feature of the studied area consists of very well preserved remnants of the former stands of this association on Lakes Jarun and Bundek in the Town of Zagreb.

Forests of bogs and micro-depressions
Šume udubina i niza

This group is composed of forest associations in which the edifying species are the pedunculate oak, black alder, narrow-leaved ash, lowland elm and spreading elm. They inhabit depressions ranging in size from half a hectare, which mostly belong to forests of black alder or ash, to a complex of several hundred ha with forests of pedunculate oak. In the past these forests were regularly flooded. Today, however, depending on the terrain orography and the distance from rivers, some parts are periodically flooded, while others only have a high level of groundwater and long-standing (stagnant) precipitation water due to specific soil composition. There are three basic associations in the entire studied area, of which the forest of pedunculate oak and great green weed (*Genisto elatae-Quercetum roboris* Ht. 1938) is shown in two sub-associations due to humidity.

The forest of black alder with buckthorn (*Frangulo-Alnetum glutinosae* Rauš 1968). The forest of black alder with buckthorn is fragmentarily arranged over an area of several ha. It grows in specific micro-relief and hydrological conditions. Most commonly, these are old beds of waterways and sometimes swamps. The pioneering role of the black alder comes to light here, because the moment suitable conditions are formed, the tree covers the old waterways and over several generations creates normal forest soil and conditions for the growth of other tree species. It is found in all management units of the lowland region, especially in Žutica and the Pokuplje basin.

The forest of black alder with buckthorn is developed on organogenic-swampy soil of mildly acid reaction with about 5.7 pH at a depth of 50 cm. The phytocoenosis is covered with 20 - 70 cm-deep surface water (sometimes more) for the most part of the year. This stagnant surface water is the reason why black alder develops special conical butts which collect mud and turn it into soil, so the alder manages to vegetate despite surface water covering a part of its root system.

The most important species in the tree layer is black alder (*Alnus glutinosa*) with frequent occurrence of narrow-leaved ash (*Fraxinus angustifolia*) and spreading elm (*Ulmus laevis*).

The shrub layer, ranging from 1 to 10%, is rather poor in cover. Apart from the species from the tree layer, the most common elements in it are *Frangula alnus, Viburnum opulus* and *Salix cinerea* on the butts of black alder trees.

There are two structural units (sinusions) in the ground layer, of which one (mesophytic) develops on the conical butts of black alder trees, that is, on the soil linked to the alder root system. These cones may sometimes have a diameter of 1 to 2 meters at the soil base and a height of 50 to 120 cm above the level of stagnant water. They are home to *Dryopteris carthusiana, Sympthytum tuberosum, Glechoma hederacea, Rubus caesius, Solanum dulcamara* and others, as well as to some mosses.

The other (hygrophytic) sinusion of the ground vegetation occurs on the soil itself, between the cones of black alders, and is made up of distinct hygrophytes, such as *Polygonum lapatifolium, Galium palustre, Sium latifolium, Lythrum salicaria, Stachys palustris, Lemna trisulca, Roripa amphibia, Hottonia palustris, Iris pseudacorus, Glyceria fluitans, Glyceria maxima, Symphytum officinale, Caltha palustris, Sparganium erectum, Urtica radicans, Peucedanum palustre* and many others. The entire floral composition of the association in the studied area can be seen in Table 1, columns 1 and 2.

The syndynamic development of the forest of black alder with buckthorn is very interesting, above all due to the pioneering and ameliorative role played by the black alder in the lowland region of Croatia. There are three stages in its development: in the initial stage beginning in old waterways, only the ground vegetation of rushes and similar is developed, to continue onto grey sallow, white sallow, fragile willow, buckthorn, white poplar, narrow-leaved ash and black alder on micro-elevations (slight undulations, facies: *Glyceria maxima*).

The black alder originating from seed and stump, with or without a conical butt and with an addition of spreading elm with narrow-leaved ash is in the optimal developmental stage.

In its terminal stage, the black alder is gradually declining and giving place to the pedunculate oak, and even a sporadic maple and common hornbeam.

We should point out that in the case of the association *Frangulo-Alnetum glutinosae*, black alder forests did not develop from the glacial, but represent pioneering and transitional stands in which the black alder has invaded the terrain, formed it phytocoenosis and gradually created conditions for the occurrence of other species. All these processes in current stands of black alder have taken place over the past few centuries, and can be accelerated with ameliorating the terrain (regulating water with canals). However, this is not necessary because these sites are highly diverse biologically owing to the annual rhythm of changes in the conditions. For this reason, they form not only important phytocoenoses, but also various zoocoenoses.

The forest of narrow-leaved ash with autumn snowflake *(Leucoio-Fraxinetum angustifoliae* Glav. 1959). The forest of narrow-leaved ash with autumn snowflake extends over a clayly alluvial terrain from Sisak to Spačva. In some earlier research and in the one conducted for this study, it was also found in the Česma basin, in Turopoljski Lug and in a large part of Pokuplje basin.

The most important factors determining the development of the association are the micro-relief and the relating stagnant and groundwater. The soil is distinctly undulating and can be neutral to acid. Of all the lowland phytocoenoses, this one is the most subjected to longer periods of surface water and high groundwater. In the winter, surface water (with an average depth of 1 m) often freezes and ice inflicts extensive damage on ash trees. Therefore, the micro-relief characteristics of the depressive terrain, the regime of high water and the properties of the soil are the fundamental ecological factors that determine the phytocoenosis.

In terms of orography, the phytocoenosis invades depressions (bogs and plates), open or closed holes in the soil. Water either runs from the higher plates to the lower (open) ones, or when it cannot leave at all (closed), it evaporates. In these bogs there are deeper plates in which precipitation water from the neighbouring areas collects and stagnates and only leaves with evaporation. Such shallow depressions are conducive to the growth of a typical forest of narrow-leaved ash, since ash has reached the extreme boundary of forest survival (swampy forest boundary). Marshy ground lying in deeper depressions is not covered with forest trees.

Narrow-leaved ash forms pure stands because the competitive ability of other tree species is weak. The tree layer covers 60 to 80 % of the area on average and is composed of narrow-leaved ash in the dominant storey with a rare presence of lowland elm, spreading elm and sometimes pedunculate oak.

The shrub layer is poorly developed and covers 0 to 5% of the area on average. Apart from tree species in the form of shrubs, it is also composed of *Genista elata, Frangula alnus, Salix cinerea* and others.

The layer of the ground vegetation covers 80 to 100 % of the area. It is very lush and is made up of a large number of species, shown in Table 1, columns 3 and 4.

Narrow-leaved ash is an outstandingly important tree species in the planar belt of Croatia from several standpoints. Apart from being important as a pioneering tree species, it grows in unfavourable, mostly swampy conditions in which other tree species cannot survive and where it does not meet any competition. Moreover, when stands of pedunculate oak in the association *Genisto elatae-Quercetum roboris* desiccate due to bogging or other changes in the biotop, ash is an unavoidable species in salvaging the stand after dieback. In the first phase, until conditions for the recurrence of pedunculate oak are created, it takes on the main role together with the black alder. This was shown in the recovery of the forests Kalje, Turopoljski Lug, the forests in the Pokuplje basin and in other places. To sum it up, ash is a highly desirable and valued economic species, which may reach the same price as pedunculate oak under certain conditions.

The forest of pedunculate oak with great green weed *(Genisto elatae-Quercetum roboris* Ht. 1938). Natural sites of pedunculate oak in the studied area are the micro-depressions of the Posavina, Pokuplje and Česma basins, especially the complex between the motorway and the river Sava. The forests of Žutica, Jastrebarski Lugovi, Draganički Lugovi, Turopoljski lug and others are located here. Pedunculate oak forms two basic forest associations: the forest of pedunculate oak and great green weed in micro-depressions and the forests of pedunculate oak and common hornbeam on micro-elevations.

The forest of pedunculate oak and great green weed occurs above the forests of willow, poplar, black alder and narrow-leaved ash in complexes exceeding several thousand ha, which is unique in Europe and in the world. The terrain on which it grows is several meters above the normal level. It is periodically flooded, but floods last for short periods, or the terrain is out of reach of floods but still abundantly fresh. It is found on mineral-swampy soil of stronger or weaker acidity and on pseudogleyic, or podzolic, mildly acid to neutral soil.

The lush tree layer is dominated by pedunculate oak, but a considerable share of the composition (sometimes even 40%) consists of narrow-leaved ash, black alder, lowland elm, spreading elm, black and white poplar and sporadic fruit-bearing trees. In the western part of the association there are pure oak forests, the result of bad management and excessive felling of other tree species, which today has a negative effect on the stability of hundred-year-old stands. Nowhere has the necessity of supporting mixed stands in their natural composition been shown more clearly than in this association, because it is a prerequisite for stability, biological diversity and productivity of forest stands.

The shrub layer is also lush and diverse, which makes this association fundamentally different from the forest of pedunculate oak and common hornbeam. Apart from the species in the tree layer, the cover of 10 to 50 % consists of great green weed (*Genista elata*), hawthorn (*Crataegus oxyacantha*), common hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*), wild pear (*Pyrus pyraster*), guelder rose (*Viburnum opulus*), buckthorn (*Frangula alnus*), blackberry (*Rubus caesius, Rubus fruticosus*), rose (*Rosa* sp.) and other species.

The layer of ground vegetation has a cover of 80 to 100% and is particularly lush in the spring after floods. It consists of some hundred species (Table 1, columns 5-8), of which the most important are *Carex remota, Carex strigosa, Rumex sanquineus, Cerastium sylvaticum, Valeriana dioica, Lycopus europaeus, Solanum dulcamara, Glechoma hederacea, Poa trivialis* and others.

The eco-indicative properties of the species in the ground layer in general point to the characteristics of the site and especially to its hydrological conditions. The majority of these and other species thriving in the forest of pedunculate oak and great green weed indicate humid, wet and occasionally flooded sites. The species leading to extremes, that is, to dry or complete swampy and flooded terrains, are absent.

From a phytocoenological standpoint, the forest of pedunculate oak and great green weed is divided into several sub-associations, but two are of special importance for the studied area: with quaking sedge (*Genisto elatae-Quercetum roboris caricetosum brizoides* Ht 1938), and with remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae* Ht 1938). The sub-association with remote sedge represents the optimum in the development of this association in which the renowned Slavonia oak thrives, while the sub-association with quaking sedge represents a transition towards pedunculate-hornbeam forests on micro-elevations and is susceptible to changes and forest decline. An example of this is Turopoljski Lug, Kalje near Lekenik, Žutica and other forests.

Forests of micro-elevations
Šume mikrouzvisina

Micro-elevations out of reach of floodwater, in which groundwater is much lower than in previously described associations, have been differentiated in the course of lowland region development. They are home to pedunculate oak, common hornbeam and even common beech in some places. This is an important vegetative

Table 1. Forest associations of flooded areas
Tablica 1. Šumske zajednice poplavnih područja

Association:	*Frangulo-Alnetum glutinosae*		*Leucoio-Fraxinetum angustifoliae*		*Genisto elatae-Quercetum roboris*			
Subassociation	*typicum*		*alnetosum glutinosae*		*caricetosum brizoides*		*caricetosum remotae*	
Area:	Žutica	Česma	Žutica	Pokupski bazen	Žutica	Pokupski bazen	Žutica	Pokupski bazen
Number of recordings:	10	5	10	5	10	10	10	5
Plot size (m^2):	400	400	400	400	400	400	400	400
FLORAL COMPOSITION								
Characteristic and distinguishing species of the alliance (*Alnion glutinosae*):								
Frangula alnus Mill. B	V	IV	III	IV	V	V	III	V
Salix cinerea L.	IV	IV	II	I	I	II	I	IV
Solanum dulcamara L. C	V	III	III	IV	III	III	II	II
Myosotis palustris L.	III	I	III	II	IV	IV	III	IV
Galium palustre L.	V	IV	V	V	IV	III	V	V
Peucedanum palustre (L.) Monch.	V	III	IV	III	III	IV	III	III
Iris pseudacorus L.	IV	III	IV	IV	III	I	V	V
Ranunculus repens L.	I	I	III	V	II	III	IV	V
Lysimachia vulgaris L.	III	V	IV	I	III	V	IV	V
Cardamine dentata L.	II	.	II	V	I	II	I	II
Leucoium aestivum L.	II	I	III	V	.	.	III	I
Carex elongata L.	III	V	II	II	II	.	III	I
Frangula alnus Mill.	.	.	.	I	I	II	.	I
Carex riparia Curt.	V	V	III	II	.	.	I	II
Roripa amphibia (L.) Bess.	II	.	I	.	.	.	I	.
Sium latifolium L.	I	.	.	IV	.	.	.	.
Urtica radicans Balla.	.	III	.	.	.		.	.
Characteristic and distinguishing species of the alliance (*Alno-Quercion roboris*):								
Genista tinctoria subs. *elata* B	.	.	II	II	I	III	II	I
Viburnum opulus L.	I	II	.	III	II	III	I	IV
Rumex sanquineus L. C	I	.	III	III	III	III	III	IV
Cerastium silvaticum W.K.	I	.	I	.	II	I	III	.
Lycopus europaeus L.	III	.	IV	II	IV	II	III	IV
Lysimachia nummularia L.	I	.	II	V	III	V	IV	V
Glechoma hederacea L.	II	.	II	IV	IV	I	IV	V
Caltha palustris L.	I	II	II	IV	.	I	II	V
Stachys palustris L.	III	III	IV	V	II	III	III	V
Carex remota L.	I	.	III	V	II	.	V	V
Carex strigosa Huds.	.	.	.	V	.	.	III	V
Valeriana dioica L.	.	.	II	V	I	II	I	III
Viburnum opulus L.	.	.	I	III	.	I	.	II
Genista tinctoria subs. *elata*	.	.	.	.	.	II	.	I
Characteristic and distinguishing species of order (*Alnetalia glutinosae*) and class (*Alnetea glutinosae*):								
Quercus robur L. A	I	I	I	V	V	V	V	V
Alnus glutinosa (L.) Gartn.	V	V	IV	V	V	IV	II	V

Fraxinus angustifolia Vahl.	I	II	V	V	II	I	I	IV
Ulmus carpinifolia Gled.	.	.	.	V	I	I	.	II
Ulmus laevis Pall.	.	III	III	III	.	.	.	I
Populus alba L.	.	.	.	.	.	.	.	I
Ulmus carpinifolia Gled. B	I	III	I	II	IV	I	III	IV
Acer tataricum L.	I	.	I	.	I	.	I	.
Sambucus nigra L.	I	I	.	I	I	I	I	III
Alnus glutinosa (L.) Gartn.	III	IV	III	II	IV	IV	III	IV
Ulmus laevis Pall.	I	III	.	II	.	.	II	.
Quercus robur L.	I	.	I	I	I	II	.	I
Fraxinus angustifolia Vahl.	I	IV	IV	III	II	I	IV	III
Rubus ceasius L.	I	.	IV	II	.	IV	.	I
Populus alba L.	.	.	I	.	.	I	.	II
Spirea salicifolia L.	.	I	.	.	.	.	.	.
Quercus robur L. C	.	.	II	.	II	V	III	V
Nephrodium spinulosum Strempel.	V	III	III	III	II	IV	I	III
Impatiens noli tangere L.	I	.	I	.	II	I	I	II
Rubus ceasius L.	III	I	.	III	IV	III	V	III
Angelica silvestris L.	I	.	I	I	II	I	I	II
Carex brizoides L.	I	.	.	.	V	V	.	III
Fraxinus angustifolia Vahl.	.	.	.	I	.	.	I	.
Ulmus carpinifolia Gled.	.	.	.	.	.	II	I	.
Acer tataricum L.	.	.	.	.	.	.	I	.
Alnus glutinosa (L.) Gartn.	.	.	.	I	.	I	.	I
Characteristic species of order (*Fagetalia*) and class (*Querco-Fagetea*):								
Carpinus betulus L. A	.	.	.	III	II	II	.	III
Acer campestre L.	.	.	I	.	I	I	.	.
Pyrus pyraster (L.) Borkh.	.	.	.	I	.	I	.	I
Crataegus oxyacantha L. B	I	.	II	IV	III	IV	III	V
Prunus spinosa L.	I	II	.	II	II	II	I	I
Pyrus pyraster (L.) Borkh.	I	.	I	II	II	III	I	I
Carpinus betulus L.	.	.	.	.	III	III	.	III
Corylus avellana L.	I	.	.	.	I	V	.	II
Acer campestre L.	I	.	.	.	III	II	II	III
Crataegus monogyna Jacq.	I	.	.	II	II	III	I	II
Euonimus europaea L.	.	.	I	II	I	II	I	I
Circaea lutetiana L. C	III	.	I	.	IV	II	II	II
Urtica dioica L.	IV	II	IV	V	IV	I	V	III
Aegopodium podagraria L.	II	.	I	.	I	II	I	V
Humulus lupulus L.	I	.	II	I	II	I	I	I
Lamiastrum galeobdolon (L.) E. et P.	.	.	.	.	I	II	.	I
Brachypodium silvaticum (Huds.) R.S.	.	.	I	.	II	.	.	.
Paris quadrifolia L.	.	.	.	.	I	.	.	.
Galium odoratum (L.) Scop.	I	.	.	.	I		.	
Geranium robertianum L.	.	.	.	.	I	II	.	I
Stellaria holostea L.	.	.	.	.	I	IV	.	.
Veronica montana L.	.	.	.	.	II	III	.	II
Viola reichenbachiana Jor. ex Bor.	.	.	.	.	I	I	I	I
Scrophularia nodosa L.	.	.	.	.	.	III	I	III
Ajuga reptans L.	.	.	I	.	I	IV	I	III

Geum urbanum L.	I	.	I	.	I	I	I	I
Dryopteris filix mas (L.) Sch.	.	.	.	.	IV	II	I	.
Acer campestre L.	.	.	I	.	.	I	I	.
Polygonatum multiflorum (L.) All.	I	.	.	.	.	.	.	.
Crataegus oxyacantha L.	.	.	.	.	.	.	.	I
Ranunculus lanuginosus L.	.	.	.	.	.	I	.	.
Carex silvatica Huds.	.	.	.	.	I	I	.	.
Arum maculatum L.	.	.	.	.	I	.	.	.
Euonimus europaea L.	.	.	.	II	.	.	.	.
Carex maxima Huds.	.	.	.	.	.	I	.	II
Cucubalus baccifer L.	.	.	.	.	.	I	.	I
Leucoium vernum L.	.	.	.	.	.	I	.	I
Other species of wet and flooded sites:								
Polygonum hydropiper L. C	III	III	IV	III	IV	III	III	III
Deshampsia caespitosa (L.) Beaur.	I	.	I	I	V	IV	II	I
Symphytum officinale L.	I	.	I	.	I	.	III	.
Carex elata All.	II	III	IV	II	.	.	II	II
Euphorbia palustris L.	II	I	IV	.	.	.	IV	.
Poa palustris L.	.	.	I	.	I	III	I	I
Juncus effusus L.	I	.	II	II	III	V	III	V
Senecio fluviatilis Wallr.	.	.	.	.	II	.	I	II
Festuca gigantea (L.) Vill.	I	.	I	.	I	.	I	.
Lytrum salicaria L.	II	.	III	II	III	II	II	III
Succisa pratensis Mch.	.	.	I	II	I	I	I	V
Alisma plantago aquiatica L.	I	III	I	.	I	.	.	I
Carex vulpina L.	.	.	I	.	.	.	I	.
Carex vesicaria L.	III	III	V	I	.	.	I	.
Mentha aquatica L.	I	I	I	III	.	II	I	III
Thalictrum flavum L.	.	.	I	.	.	.	I	.
Stellaria aquiatica	.	.	.	.	.	.	I	.
Sparganium erectum L.	III	.	.	.	.	.	.	.
Lemna trilusca L.	I	I	.	.	.	.	.	.
Hottonia palustris L.	I	I	.	.	.	.	.	.
Lemna minor L.	I	II	.	.	.	.	.	.
Senecio aquiatica Huds.	I	I	I	.	.	.	.	.
Cardamine flexuosa With.	.	.	.	III	.		.	
Filipendula ulmaria (L.) Maxim.	.	.	.	.	.	.	I	III
Chrysosplenium alternifolium L.	.	.	.	I	.	.	.	.
Glyceria fluitans (L.) R. Br.	.	I	.	.	.	.	.	III
Other species:								
Fraxinus americana A	I	.	.	.	.	.	.	.
Malus silvestris (L.) Mill.	.	.	.	II	.	I	.	I
Rhamnus cathartica L. B	II	II	I	III	I	I	III	.
Cornus sanquinea L.	I	.	.	III	I	II	I	II
Rosa canina L.	.	.	.	.	I	I	I	II
Fraxinus americana	I	.	I	.	.	.	.	.
Amorpha fruticosa L.	.	.	I	.	.	.	.	.
Galeopsis tetrahit L. C	IV	.	III	.	V	V	III	.
Hedera helix L.	.	.	I	.	I	.	I	.

Athyrium filix femina (L.) Roth.	I	.	I	.	III	II	I	.
Prunella vulgaris L.	.	.	.	.	I	II	I	II
Pulmonaria officinalis L.	.	.	.	.	I	.	I	.
Aristolochia clematitis L.	I	.	.	.	I	.	I	.
Hypericum acutum L.	.	.	.	.	II	.	I	.
Lychnis flos cuculi L.	I	.	I	.	I	I	I	I
Bidens tripartitus L.	II	.	.	.	I	I	I	I
Agrostis alba L.	.	.	.	.	I	.	I	.
Stellaria media (L.) Mill.	.	.	I	.	.	.	II	.
Galium aparine L.	.	.	.	.	I	.	.	.
Ballota nigra L.	.	.	.	.	I	.	.	.
Eupatorium canabinum L.	III	.	.	.	I	II	.	.
Moehringia trinervia (L.) Clairv.	I	.	.	.	.		.	
Trifolium repens L.	.	.	.	.	.	II	.	I
Rhamnus cathartica L.	.	.	I	II	.	.	.	.
Torilis anthriscus (L.) Gmel.	.	.	.	.	I	.	.	
Galium silvaticum L.	II	.	I	.	I	.	.	.
Amorpha fruticosa L.	.	.	.	.	.	.	I	.
Solidago sp.	.	.	.	.	.	.	I	.
Melandrium rubrum Garcke.	I	.	I	.	.	.	I	.
Tamus communis L.	.	.	.	.	.	.	I	.
Vitis silvestris Gmel.	I	.	.	.	.	.	.	.
Ranunculus ficaria L.	.	.	.	II	.	I	.	II
Melampyrum silvaticum L.	.	.	.	.	.	II	.	.
Potentilla erecta (L.) Hampe.	.	.	.	.	.	III	.	.
Cynanthum vincetoxicum (L.) Pers.	.	.	.	.	.	I	.	.
Verbatum album	.	.	.	.	.	II	.	.

Explanation of abbrevations: A - Tree layer, B - Shrub layer, C - Ground vegetation layer, I - V - Degree of participation

property of this part of Croatia, because the stands in Stupnički Lug, Kupčina, Gornjak in Turopoljski Lug, Bukovac near Vrbovec Dubrava and in Žutica have special significance.

It should be pointed out that in the floral and systematic sense, this association is fundamentally different from the forest of pedunculate oak, although both are found in the planar belt and are often intertwined. The forest of pedunculate oak with common hornbeam belongs to the alliance *Carpinion betuli* and the order *Fagetalia,* and by its composition and synecological conditions it resembles the west and central European association *Stelario-Carpinetum.*

The forest of pedunculate oak and common hornbeam *(Carpino betuli-Quercetum roboris* Rauš 1969). One of the best-known and best-studied forest associations is found in the lowland part of Croatia and in the valley of the river Mirna in Istria. The largest complexes occur in the Spačva Basin and along the entire course of the river Sava in Croatia.

The soil of this forest is not exposed to flooding, but is saturated with water in winter. In its composition the forest differs considerably from the forest of pedunculate oak with great green weed. It occurs on drained, but abundantly fresh terrains and is developed on mildly acid to neutral pseudogleyic, that is, podzolic soils on elevations. This type includes the most highly situated pedunculate oak forests in the Croatian lowland region. There is considerable participation of common hornbeam and maple, as well as a number of shrubs and herbaceous plants of drained terrain, such as those growing in hilly regions.

Common hornbeam is the best indicator of stagnant water and groundwater, because it tolerates short, passing floods, but does not tolerate stagnant water and high levels of groundwater. It grows only up to the medium groundwater table between 2 and 3 m, which is found only on elevations (Dekanić 1962).

Pedunculate oak, which plays a decisive role in the structure of a typical forest, is different in this respect. It has a large share in the phytocoenosis and exerts a vital influence on its structure and economic value. In spite of this, pedunculate oak is far less important for limited communities (associations and sub-associations) than common hornbeam because it also occurs equally frequently in the association with great green weed, to which the association with common hornbeam is connected in vertical sense.

The shrub layer is poor in species and often contains *Corylus avellana, Cornus sanguinea, Euonimus europaea, Rosa arvensis, Daphne mezereum, Crataegus* sp., and other species, while the ground vegetation consists of the species from the alliance *Carpinion betuli* and the species thriving on fresh and humid terrains. The phytocoenological composition is shown on the basis of 30 recordings in Table 2.

The mentioned characteristics refer to a typical sub-association (*subas. typicum*) while another significant sub-association in the studied area is that with beech (*Carpino betuli-Quercetum roboris fagetosum* Rauš 1971).

The pedunculate oak - hornbeam forest with beech is a relict association that inhabits the lowland regions of Croatia within a typical forest of pedunculate oak and common hornbeam. It grows on lowland pseudogley, exclusively on micro-elevations out of reach of floodwater, where beech has remained since the Sub-Boreal period, when it spread low down into the plains and invaded the present sites of pedunculate oak (Soó 1940). The soil is drained but fresh, mildly acid to neutral. The association grows in fragments of several hectares in about fifty lowland localities in Croatia and is incomparably less represented than a typical sub-association. Among the most famous localities are those in the Zagreb County and even Stupnički Lug and a part of Maksimir Park in the City of Zagreb.

The composition of ground vegetation makes this forest significantly different from a typical forest of pedunculate oak and common hornbeam, primarily in terms of differentiating species *Fagus sylvatica, Mercurialis perennis, Dentaria bulbifera, Cardamine trifolia, Allium ursinum, Luzula pilosa, Maianthemum bifolium, Anemone hepatica, Ruscus aculeatus, Rubus hirtus, Staphylea pinnata* and others. In phenological sense, the phytocoenosis is characterised by early flushing of hornbeam and beech, while pedunculate oak starts leafing only ten days after.

Mixed forests of pedunculate oak, common hornbeam and beech came into being during secular climate changes and in the past extended over much larger areas in the Pannonian Plain.

Table 2. Floral composition of mesophylic oak forest
Tablica 2. Florni sastav mezofilnih hrastovih šuma

Association:		*Carpino betuli-Quercetum roboris* Rauš 1969		*Epimedio-Carpinetum betuli* (Hr. 1938) Borh. 1963	
Area:		Žutica	Pisarovina	Sljeme	Vukom. Gorice
Number of recordings:		20	10	10	25
Plot size (m²):		400	400	400	100-500
FLORAL COMPOSITION					
Characteristic and distinguishing species of the association (*Carpino betuli-Quercetum roboris*):					
Quercus robur L.	A	V	V	.	I
Quercus robur L.	B	I	.	.	.
Ruscus aculeatus L.		II	.	.	.
Veronica montana L.	C	IV	II	.	.
Quercus robur L.		IV	V	.	.
Carex brizoides L.		IV	III	.	.
Lysimachia nummularia L.		II	I	.	.
Carex remota L.		II	I	.	.
Glechoma hederacea L.		I	II	.	.
Luzula pilosa (L.) Willd.		I	.	.	.
Characteristic and distinguishing species of the association (*Epimedio-Carpinetum betuli*):					
Quercus petraea Lieb.	A	.	.	V	V
Fagus sylvatica L.		III	II	V	V
Prunus avium L.		.	.	I	I
Castanea sativa Mill.		.	.	III	I
Fraxinus ornus L.		.	.	I	.
Fagus sylvatica L.	B	I	I	V	IV
Quercus petraea Lieb.		.	.	IV	IV
Rosa arvensis Huds.		.	.	III	I
Prunus avium L.		.	.	II	I
Lonicera caprifolium L.		.	.	II	III
Castanea sativa Mill.		.	.	IV	I
Fraxinus ornus L.		.	.	III	.
Staphylea pinnata L.		.	.	I	.
Knautia drymeia Heuff.	C	.	.	IV	III
Prunus avium L.		.	.	IV	II
Quercus petraea Lieb.		.	.	IV	V
Fagus sylvatica L.		I	I	IV	II
Primula vulgaris Huds.		II	.	II	III
Lonicera caprifolium L.		.	.	II	IV
Helleborus dumetorum W. K.		.	.	I	.
Luzula luzuloides (Lam.) D. W.		.	.	IV	II
Erythronim dens canis L.		.	.	II	.
Castanea sativa Mill.		.	.	III	I
Staphylea pinnata L.		.	.	I	.
Hacquetia epipactis (Scop.) DS.		.	.	II	.
Salvia glutinosa L.		.	.	I	I
Carex pilosa Scop.		.	.	II	.
Hepatica nobilis Schreb.		.	.	II	.
Fraxinus ornus L.		.	.	I	.

Characteristic and distinguishing species of the alliance (*Carpinion betuli*) and distinguishing species of suballiance (*Lonicero-Carpinenion*):				
Carpinus betulus L. A	V	V	IV	V
Quercus cerris L.	.	.	I	I
Corylus avellana L.	.	.	.	I
Acer campestre L.	.	.	.	II
Carpinus betulus L. B	IV	IV	IV	V
Euonimus europaea L.	III	I	I	.
Acer campestre L.	III	I	II	III
Corylus avellana L.	III	V	V	V
Quercus cerris L.	.	.	I	.
Ruscus hypoglossum L.	.	.	I	II
Stellaria holostea L. C	IV	II	II	IV
Vinca minor L.	I	I	.	.
Acer campestre L.	II	.	II	II
Carpinus betulus L.	II	.	IV	IV
Euonimus europaea L.	.	II	.	.
Aposeris foetida (L.) Cass.	.	.	IV	IV
Cruciata glabra (L.) Ehrend.	.	I	III	III
Cyclamen purpurascens Mill.	.	.	III	II
Vicia oroboides Wulf.	.	.	II	.
Lamium orvala L.	.	.	I	.
Epimedium alpinum L.	.	.	III	IV
Quercus cerris L.	.	.	I	.
Melampyrum nemorosum L.	.	.	II	.
Corylus avellana L.	.	.	.	II
Euphorbia dulcis L.	.	.	.	II
Cardamine savensis Schulz.	.	.	.	I
Characteristic species of order (*Fagetalia*) :				
Pyrus pyraster (L.) Borkh. A	I	II	.	II
Ulmus glabra Mill.	.	.	I	.
Acer pseudoplatanus L.	.	.	.	I
Acer platanoides L.	.	.	.	I
Crataegus oxyacantha L. B	III	V	I	.
Crataegus monogyna Jacq.	II	II	I	II
Daphne mezereum L.	.	.	III	I
Pyrus pyraster (L.) Borkh.	I	II	I	III
Acer pseudoplatanus L.	.	.	II	I
Ulmus glabra Mill.	.	.	I	.
Circaea lutetiana L. C	V	III	I	I
Viola reichenbachiana Jor. ex Bor.	V	III	III	II
Lamiastrum galeobdolon (L.) E. et P.	V	IV	I	III
Polygonatum multiflorum (L.) All.	V	III	III	III
Ajuga reptans L.	V	IV	I	I
Dryopteris filix mas (L.) Sch.	IV	III	I	II
Brachypodium silvaticum R.S.	III	I	.	II
Carex silvatica Huds.	II	I	II	V
Asarum europaeum L.	II	I	II	V
Scrophularia nodosa L.	II	III	II	.
Galium odoratum (L.) Scop.	V	.	IV	IV
Carex maxima L.	III	.	.	.

Anemone nemorosa L.	III	.	IV	.
Paris quadrifolia L.	III	.	.	.
Pulmonaria officinalis L.	I	.	IV	III
Sanicula europaea L.	I	.	IV	V
Euphorbia amygdaloides L.	I	.	I	I
Lathyrus vernus (L.) Borh.	.	I	IV	II
Dentaria bulbifera (L.) Cr.	.	.	III	I
Acer pseudoplatanus L.	.	.	III	I
Acer platanoides L.	.	.	II	
Mycelis muralis (L.) Rchb.	I	.	II	II
Symphytum tuberosum L.	III	I	IV	
Platanthera bifolia (L.) Rich.	I	.	II	I
Senecio nemorensis L.	I	.	II	
Melica uniflora Retz.	.	.	I	I
Mercurialis perennis L.	.	.	II	.
Alliaria petiolata Scop.	.	.	II	.
Ulmus glabra Mill.	.	.	I	.
Heracleum sphondylium L.	.	.	II	.
Ranunculus lanuginosus L.	.	.	II	I
Crataegus monogyna Jacq.	.	.	I	I
Lilium martagon L.	.	.	I	.
Phyteuma spicatum L.	.	.	II	.
Daphne mezereum L.	.	.	.	I
Oxalis acetosella L.	.	.	.	I
Pyrus pyraster (L.) Borkh.	.	.	.	I
Characteristic species of class (*Querco-Fagetea*):				
Sorbus torminalis (L.) Cr. A	.	.	.	I
Viburnum opulus L. B	II	III	I	I
Sorbus torminalis (L.) Cr.	.	.	II	I
Cornus sanquinea L.	.	.	I	II
Ligustrum vulgare L.	.	II	II	II
Chamaecytisus hirsutus (L.) Lk.	.	.	.	I
Tilia cordata Mill.	.	.	.	I
Rubus caesius L.	I	IV	.	III
Prunus spinosa L.	.	.	.	I
Euphorbia dulcis L. C	.	I	V	.
Hedera helix L.	III	IV	IV	III
Festuca drymeia L.	.	.	III	I
Tamus communis L.	.	.	II	.
Potentilla micrantha Ram.	.	.	II	.
Lathyrus niger (L.) Bernh.	.	.	II	I
Melittis melissophylum L.	.	.	II	I
Tanacetum corymbosum (L.) S.-B.	.	.	II	.
Sorbus torminalis (L.) Cr.	.	.	.	II
Cornus sanquinea L.	.	.	.	I
Campanula trachelium L.	.	.	.	I
Clematis vitalba L.	.	.	.	I
Viburnum opulus L.	.	.	.	I
Chamaecytisus hirsutus (L.) Lk.	.	.	.	I
Ligustrum vulgare L.	.	.	.	I

Other species:					
Alnus glutinosa (L.) Gaertn.	A	.	.	.	I
Fraxinus angustifolia Vahl.		.	I	.	.
Malus silvestris L.		.	I	.	.
Ulmus carpinifolia Gled.	B	II	II	.	.
Sambucus nigra L.		I	II	.	.
Frangula alnus Mill.		I	III	.	.
Rhamnus cathartica L.		III	.	.	.
Fraxinus angustifolia Vahl.		.	II	.	.
Rosa canina L.		.	I	.	.
Juniperus communis L.		.	.	.	II
Betula pendula Roth.		.	.	.	I
Robinia pseudacacia L.		.	.	.	I
Oxalis acetosella L.	C	V	I		.
Galeopsis tetrahit L.		V	IV	.	II
Fragaria vesca L.		III	II	V	III
Rubus hirtus W.K.		IV	.	IV	I
Geum urbanum L.		II	I	.	.
Aegopodium podagraria L.		II	I	.	I
Athyrium filix femina (L.) Roth.		II	IV	.	III
Angelica silvestris L.		II	I	.	.
Festuca gigantea (L.) Vill.		II	I	.	.
Urtica dioica L.		I	I	.	.
Deschampsia caespitosa (L.) Beauv.		I	V	.	.
Melampyrum silvaticum L.		I	II	.	II
Nephrodium spinulosum Stremp.		I	I	.	.
Lapsana communis L.		I	I	.	.
Cerastium silvaticum W.K.		II	.	.	I
Impatiens noli tangere L.		II	.	.	.
Hieracium racemosum W. K.		.	.	III	II
Geranium robertianum L.		I	.	.	.
Hieracium sylvaticum L.		.	.	II	.
Veronica chamaedrys L.		I	.	II	.
Moehringia trinervia (L.) Clairv.		I	.	.	.
Galium aparine L.		I	.	.	.
Galium palustre L.		I	.	.	.
Galium silvaticum L.		I	.	IV	I
Pteridium aquilinum (L.) Kuhn		.	.	III	IV
Hypericum hirsutum L.		I	.	.	I
Cardamine savensis Schulz.		I	.	.	.
Maianthemum bifolium (L.) Schm.		I	.	.	.
Ranunculus ficaria L.		I	.	.	.
Millium effusum L.		I	.	.	II
Myosotis scorpyoides L.		I	.	.	.
Rumex sanquineus L.		I	.	.	I
Cephalanthera rubra (L.) L.C. Rich.		I	.	.	I
Torylis anthriscus (L.) Gmel.		I	.	.	.
Euphorbia carniolica L.		.	II	.	.
Cynanchum vincetoxicum Pers.		.	II	.	I
Bidens tripartita L.		.	II	.	.

Peucedanum palustre (L.) Mch.	.	II	. .	.
Lysimachia vulgaris L.	.	I	.	.
Solidago virgaurea L.	.	.	II	I
Prenanthes purpurea L.	.	.	II	.
Polygonum hydropiper L.	.	I	.	.
Gentiana asclepiadea L.	.	I	III	I
Convallaria majalis L.	.	I	V	.
Doronicum austriacum Jacq.	.	.	II	.
Lycopus europaeus L.	.	I	.	.
Frangula alnus Mill.	.	I	.	.
Prunella vulgaris L.	.	.	.	II
Glechoma hirsuta W. K.	.	.	.	I
Lathrea squamaria L.	.	.	.	I
Explanation of abbrevations: A - Tree layer, B - Shrub layer, C - Ground vegetation layer, I - V - Degree of participation				

THE VEGETATION BELT OF LOW HILLS (COLIN)
BREŽULJKASTI (KOLINSKI) VEGETACIJSKI POJAS

This vegetation belt continues onto the lowland belt and is located between 150 and 400 (500) m above sea level. It is characterised by very favourable climate and edaphic conditions for the growth of forest vegetation. This contributes to the relatively rich floral composition and lush physiognomy of forest associations. However, this is also the reason why these forests have been largely cleared, as they grow in exceptionally favourable conditions for human life and activities. The vegetation belt of low hills consists of hills and lower slopes of the Pannonian chain. It encircles higher hills and mountains, such as Medvednica, Ivanšćica or Slavonian hills and takes up all the bordering areas below the belt of beech forests.

The principal tree species is undoubtedly sessile oak. It occurs in acidophilic, neutrophilic-mesophilic and thermophilic-basophilic associations over various geological substrates and soils. Of other tree species the more important are common hornbeam and beech, as well as sweet chestnut, birch, Turkey oak, pubescent oak, maple, cherry and other species. Depending on synecological conditions there are three groups of forest associations in the hilly belt that differ in the floral-systematic sense:

- the Central European vegetation zone of acidophilic forests growing on silicates dominated by the associations of the alliance *Castaneo-Quercion*;
- the peri-Illyrian oak-hornbeam forests of the sub-alliance *Lonicero caprifoliae-Carpinenion betuli* within the alliance *Carpinion betuli* on more or less neutrophilic soils;
- phytocoenoses belonging to the alliance *Quercion pubescentis-petraeae* within the order *Quercetalia pubescentis* occurring in the Central European vegetation zone of thermophilic forests.

Forests on acidophilic soils
Šume na kiselim tlima

These are forest associations on silicate rocks and dystric cambisols of various depths at altitudes up to 500 m. Some associations are distinctly dominated by sessile oak in pure stands, while others are mixed and composed equally of chestnuts, birches or other tree species. It is the chestnut and the acido-thermophilic species that give this alliance its south-eastern European character differing it from the Central European alliance *Quercion roboris-petraeae*. The characteristic and differentiating species of the alliance *Castaneo-Quercion* are *Castanea sativa, Chamaecytisus supinus, Genista germanica* f. *heteracantha, Hieracium racemosum, Lembotropis nigricans, Festuca heterophylla, Genista ovata*, while exclusively differentiating species are *Fraxinus ornus, Serratula tinctora, Cruciata glabra* and others. Naturally, they are combined with the species of the Central European alliance, such as *Genista tinctoria, Frangula alnus, Luzula luzuloides, Hieracium umbellatum, Calamagrostis arundinacea, Lathyrus montanus, Luzula forstery, Viola riviniana, Viscaria vulgaris, Hieracium sabaudum, Veronica officinalis* and others.

Two very interesting forest associations from this group are found in the area of the City of Zagreb and the Zagreb County.

The forest of sessile oak and sweet chestnut (*Querco-Castaneetum sativae* Ht. 1938). The forest of sessile oak and sweet chestnut builds the largest complexes on Mount Medvednica and in the surroundings of Samobor, and more rarely on other hills of the studied area. This forest thrives at altitudes between 250 and 550 m, sometimes higher, on mild slopes and dystric cambisols, typical, medium deep to deep, over clayly schists, shales and phyllites, where it achieves its full development in sociological and taxonomic sense. As a rule, the sites include warmer localities, plateaux, saddles or mild slopes where deeper soils can accumulate so that the chestnut can spread its roots 1m in depth.

The tree layer is composed of sweet chestnut and sessile oak, with frequent presence of common hornbeam and beech. However, chestnut dieback has caused the majority of the stands and even entire complexes to lose their typical floral composition and structure. As a result, the former rich chestnut forests are undergoing changes in terms of vegetation and management methods.

The shrub layer is very luscious and made up of well-known acidophytes *Chamaecytisus supinus, Lembotropis nigricans, Genista tinctoria, Genista germanica, Vaccinium myrtillus* and naturally, the species from the tree layer. The acidophilic species in the ground vegetation *Melampyrum pratense, Hieracium sylvaticum, Hieracium racemosum, Festuca heterophylla, Luzula luzuloides, Pteridium aquilinum, Lathyrus montanus, Viscaria vulgaris* and mosses *Hypnum cupressiforme* and *Polytrichum commune* are very important for the phytocoenosis (Table 3). Apart from these, favourable climatic and edaphic conditions enable the occurrence of many less acidophilic and neutrophilic species, even thermophytes such as, for example, *Fraxinus ornus*. The participation of beech and common hornbeam is very important, since they repair the empty spaces caused by chestnut dieback in some stands on plateaux. This is made possible by favourable edaphic conditions. Depending on the exposition, the association more or less transcends into acidophilic forests of beech or sessile oak with considerable presence of hornbeam on milder terrains and plateaux. This process can be seen clearly in the stands above Šestine towards Medvedgrad and above Gračani.

Disturbed and degraded stands will not be analysed here, but some steeper localities with the species *Vaccinium myrtillus* are worth mentioning.

The acido-thermophilic forest of sessile oak with hawkweed (*Hieracio racemosi-Quercetum petraeae* Vukelić /1990/ 1991). The association *Hieracio racemosi-Qercetum petraeae* is best developed on the mountains of north-western Croatia, especially on Medvednica. It occurs most commonly on the substrate of schists and sandstones, almost exclusively on southern and south-western expositions at altitudes between 300 and 750 m. It grows on ridges, crests and shallow saddles in characteristic elongated fragments, and more rarely on wide slopes. In the upper area it is usually surrounded with acidophilic beech forests, and in the lower area, where the terrain is less sloped, it ends with the association of sessile oak and chestnut. The soils are dystric cambisols, typical and illimerised, usually shallow and medium deep.

Sessile oak with its edifying role is particularly prominent in the tree layer. It frequently forms mono-dominant stands with an occasional *Sorbus torminalis,* Manna ash (*Fraxinus ornus*) and chestnut (*Castanea sativa*). Chestnut is much less frequent and has poorer vitality than in the association *Querco-Castaneetum,* because shallow soils do not allow it to grow successfully. The shrub and ground vegetation is very rich, especially in more open stands. An important role is played by characteristic species that differentiate this association from the more widely spread European association *Luzulo-Quercetum*. The majority of them are acidophilic, but in south and south-eastern Europe they have a more distinct thermophilic character and are more widely distributed. These are *Chamaecytisus supinus, Hieracium racemosum, Festuca heterophylla, Serratula tinctoria, Campanula persicifolia, Dactylis polygama, Achillea distans* and proper thermophytes such as *Tanacetum corymbosum, Lathyrus niger* and *Sedum maximum*. These species are either absent or are very rare in the related associations in Europe, which justifies the definition of this association and determines its independence - above all towards the association *Luzulo-Quercetum*. Of other species there is ample presence of *Luzula luzuloides, Melampyrum pratense, Hieracium sylvaticum, Calamagrostis arundinacea, Convallaria majalis, Solidago virgaaurea, Veronica chamaedrys, Prenanthes purpurea* and others (Table 3).

The forest of sessile oak with hawkweed is mostly of primary origin, but many stands in the north-west of Croatia are in regression as a result of anthropogenic influence, improper felling and the removal of leaf litter. In the progressive direction, the coenosis is developing towards the forests of sessile oak and sweet chestnut, and the regression ends with bracken and heath.

Table 3. Forest on acidophilic soils
Tablica 3. Šume na kiselim tlima

Association:		*Hieracio racemosi-Quercetum petraeae* Vukelić (1990) 1991	*Querco-Castanetum sativae* Ht. 1938
Area:		Medvednica	Medvednica
Number of recordings:		20	10
Plot size (m²):		250-400	300-400
FLORAL COMPOSITION			
Characteristic and distinguishing species of the association (*Querco-Castanetum sativae*):			
Castanea sativa Mill.	A	II	V
Castanea sativa Mill.	B	V	V
Hieracium sylvaticum (L.) L.	C	IV	V
Melampyrum pratense (Pers.) Ronn.		V	V
Castanea sativa Mill.		IV	V
Characteristic and distinguishing species of the association (*Hieracio racemosi-Quercetum petraeae*):			
Fraxinus ornus L.	A	I	I
Fraxinus ornus L.	B	IV	III
Chamaecytisus supinus (L.) Lk.		III	III
Chamaecytisus hirsutus (L.) Lk.		II	.
Fraxinus ornus L.	C	III	II
Galium sylvaticum L.		V	V
Tanacetum corymbosum (L.) C.H. Sch.		IV	I
Cruciata glabra (L.) Ehrend.		IV	III
Campanula persicifolia L.		IV	II
Festuca heterophylla Lam.		IV	II
Dactylis polygama Horv.		II	II
Achyllea distans W.K.		II	.
Sedum maximum (L.) Sut.		II	.
Characteristic and distinguishing species of the alliance (*Castaneo-Quercion petraeae*):			
Genista germanica L.	B	II	II
Hieracium racemosum W.K.	C	V	III
Lathyrus niger (L.) Bernh.		IV	I
Serratula tinctoria L.		II	III
Genista germanica L.		II	.
Characteristic species of order (*Quercetalia robori-petraeae*) and class (*Querco-Fagetea*):			
Genista tinctoria L.	B	III	III
Lembotropis nigricans (L.) Griseb.		II	I
Genista ovata W.K.		I	.
Frangula alnus Mill.		.	II
Luzula luzuloides (Hoffm.) DC.	C	V	V
Calluna vulgaris Hull.		II	I
Pteridium aquilinum (L.) Kuhn.		II	III
Calamagrostis arundinacea (L.) Roth.		III	I
Hieracium sabaudum L.		III	I
Hieracium umbellatum L.		II	I
Lathyrus montanus Bernh.		II	I
Genista tinctoria L.		III	.

Molinia coerulea (L.) Moench.	II	.
Avenella flexuosa (L.) Parl.	II	.
Polypodium vulgare L.	I	.
Viscaria vulgaris Bernh.	.	II
Viola riviniana Rchb.	.	II
Veronica officinalis L.	.	I
Luzula forsteri (Sm.) D.C.	.	I
Other species:		
Quercus petraea (Matt.) Liebl. A	V	V
Fagus sylvatica L.	II	V
Rubus hirtus W.K.	II	.
Carpinus betulus L.	.	II
Quercus petraea (Matt.) Liebl. B	IV	III
Fagus sylvatica L.	IV	V
Carpinus betulus L.	III	III
Corylus avellana L.	II	III
Juniperus communis L.	I	I
Sorbus torminalis (L.) Cr.	II	II
Sorbus aria (L.) Cr.	II	I
Acer pseudoplatanus L.	I	.
Quercus petraea (Matt.) Liebl. C	V	IV
Convalaria majalis L.	III	II
Vaccinium myrtillus L.	II	II
Solidago virgaurea L.	III	IV
Carpinus betulus L.	II	II
Poa nemoralis L.	II	II
Fagus sylvatica L.	I	II
Platanthera bifolia (L.) Rich.	I	II
Polygonatum multiflorum (L.) All.	I	II
Acer pseudoplatanus L.	I	I
Veronica chamaedrys L.	III	II
Lathyrus vernus (L.) Bernh	II	I
Prenanthes purpurea L.	III	II
Potentilla micrantha Ram.	II	III
Fragaria vesca L.	II	III
Cephalantera longifolia (L.) Fritsch.	II	II
Gentiana asclepiadea L.	I	II
Symphytum tuberosum L.	II	II
Euphorbia dulcis L.	II	III
Melica uniflora Retz.	II	II
Stellaria holostea L.	II	.
Kneutia drymeia Heuff.	II	.
Cephalantera alba Simk.	II	.
Melittis melyssophyllum L.	II	.
Campanula patula L.	II	.
Campanula rotundifolia L.	I	.
Dryopteris filix mas (L.) Schott.	I	.
Potentilla erecta (L.) Hampe.	I	.
Carex montana L.	I	.
Vicia sepium L.	I	.

Aposeris foetida (L.) Less.	.	IV
Rubus hirtus W.K.	.	II
Sanicula europaea L.	.	II
Asarum europaeum L.	.	II
Erythronium dens canis L.	.	II
Scrophularia nodosa L.	.	II
Pulmonaria officinalis L.	.	II
Hedera helix L.	.	II
Festuca drymeia M.K.	.	I
Prunus avium L.	.	I
Cyclamen purpurascens L.	.	I
Athyrium filix femina (L.) Roth.	.	I
Campanula trachelium L.	.	I
Galium odoratum (L.) Scop.	.	I
Dentaria bulbifera L.	.	I
Mycelis muralis (L.) Dum.	.	I
Lonicera caprifolium L.	.	I
Salvia glutinosa L.	.	I
Festuca gigantea (L.) Vill.	.	I
Primula vulgaris Huds.	.	I
Dicranum scoparium (L.) Hedw. D	I	II
Hypnum cupressiforme L.	I	III
Leucobryum glaucum (L.) Schpr.	I	I
Polytrichum commune L.	.	IV
Polytrichum formosum	III	.
Mnium undulatum (L.) Weis.	.	I
Mnium sp.	.	I
Pleurozium sp.	.	I
Explanation of abbrevations: A - Tree layer, B - Shrub layer, C - Ground vegetation layer, D - Moss layer, I - V - Degree of participation		

Thermophilic forests on alkaline soils
Termofilne šume na bazičnim tlima

This zone is not widely represented in Croatia. It consists of two clearly distinct and spatially important associations. Sessile oak (*Quercus petraea*), pubescent oak (*Quercus pubescens*), hop hornbeam (*Ostrya carpinifolia*), Manna ash (*Fraxinus ornus*), Turkey oak (*Quercus cerris*), *Acer obtusatum* and whitebeam (*Sorbus aria*) dominate in the tree layer while the species of the order *Quercetalia pubscentis* appear in other layers.

The forest of sessile oak with black pea (*Lathyro-Quercetum petraeae* Ht. /1938/ 1958). The forest of sessile oak with black pea is an unusual association belonging to the alliance *Quercion pubescentis-petraeae*. It is best developed on carbonate substrates and rendzic leptosols in warmer and more exposed localities in the hills of north-west Croatia at altitudes between 300 and 550 m. The phytocoenosis is connected with the forest of pubescent oak and hop hornbeam, but contains only some of its elements. The most important species in the tree layer are *Qu-*

ercus pubescens, Fraxinus ornus, Sorbus aria and *Quercus cerris*, and in the shrub layer *Cornus mas, Ligustrum vulgaris, Viburnum lantana* and *Berberis vulgaris*. In the ground vegetation the most important are neutrophilic-basophilic elements of which the most prominent are *Lathyrus niger, Dactylis polygama, Calamintha clinopodium, Tanacetum corymbosum, Cynanchum vincetoxicum, Melittis melissophyllum, Campanula persicifolia, Galium lucidum, Digitalis grandiflora* and others. On more shallow soils and more inclined slopes the thermophilic character of the association disappears in order to be replaced by a more acidophilic one. Hop hornbeam and other basophilic species are absent in the first place. As a result, there are the majority of indifferent, as well as acidophilic species on Kalnik, such as *Hieracium sylvaticum, Veronica chamaedys, Festuca heterophylla* and *Pteridium aquilinum* (Vukelić 1991). East of Kalnik, and even on Moslavačka Gora, there is a related, but still acidophilic phytocoenosis of sessile oak with fescue.

The forest of sessile oak and pea has a very high protective importance. The areas are fragmentary, poorly represented, and many stands in private forests in Croatian Zagorje are seriously degraded. Syndynamically, the phytocoenosis usually develops towards the forest of sessile oak and common hornbeam.

The forest of pubescent oak and hop hornbeam (*Ostryo-Quercetum pubescentis* Ht. 1938). The forest of pubescent oak and hop hornbeam occurs fragmentarily over areas of several hectares on Medvednica, Žumberak and Samoborsko Gorje. It inhabits altitudes of 300 to 600 m over alkaline substrates of marl, dolomite, lithotamnium limestones and less commonly sandstone. The most common soils are rendzic leptosols, and the terrain consists of steep, exposed, dry and warm slopes. The stands of pubescent oak are a relict of the thermophilic Tertiary vegetation which remained in extremely dry sites of the continental part of Europe in the post-glacial period and the onslaught of Central European mesophilic species. The floral composition is dominated by the species of the order *Quercetalia pubescentis*. The most important species in the tree layer are *Quercus pubescens, Quercus cerris, Ostrya carpinifolia, Acer obtusatum, Sorbus aria, Acer monspesulanum, Fraxinus ornus* and *Sorbus torminalis*, and in the shrub layer *Cornus mas, Chamaecytisus hirsutus, Clematis vitalba, Prunus spinosa, Viburnum lantana, Berberis vulgaris* and *Ligustrum vulgare*. In the ground layer there are *Tamus communis, Asparagus tenuifolius, Mercurialis ovata, Carex humilis, Trifolium rubens, Bromus erectus, Melittis melissophyllum, Litospermum purpureo-coeruleum, Dictamnus albus, Carex flacca, Brachypodium sylvaticum, Tanacetum corymbosum, Dactylis glomerata, Teucrium chamaedrys, Betonica officinalis, Cyclamen purpurascens, Galium mollugo* and others. The forest of pubescent oak and hop hornbeam is most commonly a coppice dominated by hop hornbeam. This refers primarily to privately owned forests that should be improved over a relatively longer period. However, almost all of the pubescent oak stands have a protective character and are excluded from regular management. Their true importance lies in the preservation of biological diversity and the gene fund.

Forests on neutrophilic soils
Šume na neutralnim tlima

The most important zone is the belt of higher hills in which the basic association is that of the forest of sessile oak and common hornbeam. In its floral-genetic development this forest differs from the related European oak-hornbeam forests in that it is rich with authentic Illyrian or Illyroid species. Among them special mention should be made of *Lonicera caprifolium, Epimedium alpinum, Erythronium dens canis, Vicia oroboides, Knautia drymeia, Crocus vernus, Helleborus dumetorum, Cruciata glabra, Aposeris foetida, Ruscus hyppoglossum* and others. Therefore, they are placed not only into separate associations, but also a sub-alliance, while the basic species of the alliance *Carpinion betuli* are the same as in other European *Carpinion* associations.

The Illyrian forest of sessile oak and common hornbeam (*Epimedio-Carpinetum betuli* /Ht. 1938/ Borh. 1963). This is a widely distributed climatozonal association that inhabits hills, lower mountains and foots of larger massifs, in humid climatic conditions, on eutric cambisols, luvisols and pseudogley on slopes over various substrates. Very beautiful stands are found in the entire ring around Mount Medvednica, in the hilly area between Vrbovec and Zelina, in private forests of Croatian Zagorje, and especially in the forests in Pokupsko belonging to the Forest Administration Sisak, in the area between Pokupsko, Kravarsko, Pisarovina and Velika Gorica. In the past, this association was even more widely distributed than it is today. Namely, large areas in hilly and sub-mountainous positions that potentially belonged to this association were cleared in the past and are presently used as agricultural land, vineyards, roads, industrial plants and settlements.

In his explanation why this association represents the vegetative climax of a larger part of Croatia, Horvat (1938) concludes that it is because it inhabits those habitats in which "general climatic conditions are fully present and undisturbed soil development is enabled".

The forest of sessile oak and common hornbeam grows at altitudes of 150 to 450 m on luvisols, eutric cambisols and calcocambisols over limestones and dolomites, soft limestones, conglomerates, marls and other substrates, and only the sub-association *erythronietosum* also occurs on dystric cambisols over sandstones.

In the tree layer, but also in the entire phytocoenosis, the most important edifying species is sessile oak. Apart from the oak, the understorey regularly features bigger or smaller groups of common hornbeam, one of the sociologically most significant species. Many stands, especially those in the valleys of streams and ditches, have been turned into pure hornbeam forests. Except for its sociological importance, hornbeam is also outstandingly important as an ameliorative species used in stand tending. It assists the growth of good-quality oak trees during the whole rotation, improves the soil with its leaf litter, and plays an irreplaceable role in stand regeneration. Common beech often accompanies sessile oak and hornbeam, but it does not have such big importance as in the related association *Festuco drymeiae-Carpinetum betuli*. Of trees, cherry (*Prunus avium*) and maple (*Acer campestre*) are very important, while sycamore and Norway maple (*Acer pseeudoplatanus* and *A. platanoides*), elm (*Ulmus glabra*) and chestnut (*Castanea sativa*) are less common.

In the shrub layer, the following species are important: *Rosa arvensis, Euonymus europaea, Lonicera caprifolium, Corylus avellana, Crataegus monogyna, Pyrus pyraster, Daphne mezereum* and *Crataegus oxyacantha*, while those in the ground layer are *Knautia drymeia, Primula vulgaris, Helleborus dumetorum, Stellaria holostea, Vinca minor, Melampyrum nemorosum, Cruciata glabra, Cyclamen purpurascens, Vicia oroboides, Lamium orvala, Aposeris foetida, Epimedium alpinum, Galium odoratum, Anemone nemorosa, Dentaria bulbifera, Sanicula europaea, Pulmonaria officinalis, Symphytum tuberosum, Lathyrus vernus, Viola reichenbachiana, Polygonatum multiflorum, Mycelis muralis, Carex sylvatica* and others (Table 2).

Festuca drymeia and *Rubus hirtus* are common and important plants in the regeneration of stands. They sporadically form pure facies. *Hedera helix, Galium sylvaticum, Convallaria majalis* and others are also regular accompanying species.

Mosses do not have any sociological importance for this association. However, their occurrence and wide-spread presence are the result of trampling the soil in the stands, building roads and skidding tracks, removing the leaf litter and converting these forests into pure oak forests, which will be discussed in more detail in the phytocoenosis syndynamics.

The syndynamics of the phytocoenosis *Epimedio-Carpinetum betuli* is very important because almost half of the forests of sessile oak and hornbeam are in some of the syndynamic stages. To sum it up, the removal of leaf litter, irrational felling operations, excessive trampling of the soil in the stands or other negative impacts have caused the regression to take two directions, depending on the type and depth of the soil and on the parent substrate. If the soil is acidified, hornbeam retreats from the stand and pure sessile oak stands of ever decreasing quality take its place, to be replaced by sessile coppice and finally a tangled growth dominated by various more or less acidophilic or neutrophilic shrubs. If, however, the soil becomes alkaline (shallow, more or less carbonate soils), sessile oak retreats and hornbeam remains. The forest gradually turns into a tangled growth of common hornbeam with various more or less basophilic shrubs.

In concordance with earlier correct understanding, and on the basis of phytocoenological recordings, the association *Epimedio-Carpinetum betuli* is divided into three sub-associations: *erythronietosum, caricetosum pilosae* and *staphyletosum*. All three of them occur in the studied area, which makes this area very important because the forest of sessile oak and common hornbeam with its sub-associations has been described for the first time.

THE VEGETATION BELT OF HIGHER HILLS (MOUNTAIN)
BRDSKI (MONTANSKI) VEGETACIJSKI POJAS

The vegetation belt of higher hills is very significant in the forest vegetation of the City of Zagreb and the Zagreb County because of its principal species - the common beech. It extends from 500 m above sea level to its upper boundary between 700 and 900 m, depending on the location and macroclimate. It has already been said in this work that beech alone may occur at a much lower altitude, starting from 100 m in the planar belt.

Common or European beech (*Fagus sylvatica* L.) represents the most important commercial species in the forest economy of Croatia today. In the vertical distribution of forest vegetation of the continental part of Croatia, beech is a very significant species and occurs in basic associations in almost all vegetation belts. It may occur in mixtures with other species in the planar belt at heights between 90 and 150 m, which is the belt of the forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris fagetosum*). Its share in the mixture is much more prominent in the next, hilly belt at heights of 150 to 400 m. However, it achieves the peak of its development and the highest commercial value at heights to 800 m, where it distinctly dominates climatozonal associations. Humid climate in the Illyrian hilly area is highly suitable for the beech, making it a very competitive tree species. The combination of climatic conditions in the past and present and the floral-genetic development of the flora and vegetation are the reason why Illyrian forests are so rich in species. Due to the wealth of the species, these forests have been classified into a separate alliance of Illyrian beech forests *Aremonio-Fagion*.

In the belt of higher hills there are three groups of associations differing in synecological and floral sense:

Acidophilic beech forests of the alliance *Luzulo-Fagion* in which the basic association is *Luzulo-Fagetum;*

Neutrophilic Illyrian beech forests of the alliance *Aremonio-Fagion*, which comprises the association *Lamio orvalae-Fagetum* within the sub-alliance *Lonicero-Fagenion*;

Basophilic-thermophilic beech forests of the alliance *Ostryo-Fagion* with the basic association *Ostryo-Fagetum*.

Apart from the basic forest associations in the vegetation belt of higher hills, there are several other forest associations of little economic significance but high value in phytocoenological and scientific sense. Some of them have an important protective role in repairing and covering eroded areas and steep terrains. All of them are outstandingly important for the preservation of the genofund of relatively rare authochthonous tree species. A relict forest of lime and yew (*Tilio-Taxetum*) is especially important for the studied area.

The forest of beech with woodrush (*Luzulo-Fagetum sylvaticae* Mausel 1937). Analogously to acidophilic forests of sessile oak in the hilly belt, the mountain belt is home to pure acidophilic forests of common beech (*Luzulo-Fagetum sylvaticae* Mausel 1937). They take up relatively large areas on Medvednica and Samoborsko Gorje and inhabit steep, most commonly northern slopes in the first place. They occur on shallow and medium deep dystric cambisols and podzolic soils over silicate substrates at altitudes up to 800 m.

Beech dominates in the tree layer. In lower areas, beech is accompanied with sessile oak, sweet chestnut and birch, and in higher area with fir and spruce. The shrub layer is undeveloped, with only *Genista tinctoria,* as well as *Vaccinium myrtillus* over larger areas. The ground vegetation and mosses are dominated with acidity-indicating species. These are woodrush *Luzula luzuloides, Hieracium sylvaticum* and *H. racemosum* in the first place, as well as *Pteridium aquilinum, Veronica officinalis, Melampyrum vulgatum,* and mosses *Polytrychum attenuatum, Dicranum scoparium, Dicranella heteromalla.* In cases of milder slopes and deeper soils the share of neutrophilic-mesophilic species increases and this coenosis passes into the hilly beech forest with dead nettle. These fundamentally different beech forests have not yet been accurately differentiated in our country.

Sessile oak and common beech, with intensive participation of other species, occur equally in certain transitional stands in the Žumberak and Samobor chains, especially at the points where the terrain and expositions change. Phytocoenological differentiation is difficult to carry out in such areas. Such stands were described earlier in Slovenia under the name *Querco-Luzulo-Fagetum* Mar. *et* Zup. 1979.

Table 4 shows the floral composition of this association on the basis of 25 recordings from the studied area.

The Illyrian hilly beech forest with dead nettle (*Lamio orvale-Fagetum sylvaticae* Ht. 1938). The Illyrian hilly beech forest belongs to the alliance *Aremonio-Fagion* and is the most important climatozonal association of the hilly belt in Croatia. It occurs at altitudes between 400 and 800 m on Mount Medvednica, and more rarely on other hills of the studied area. This is primarily the result of the lithological substrate and soil, because silicate and dystric cambisols support the earlier described forest of beech with woodrush. Beech forest with dead nettle thrives on various expositions, flat terrain, plateaux, less conspicuous ridges and not very steep slopes. In the Dinara region it grows most commonly on brown soils on limestones and mollic leptosols, and in the Pannonian hills it inhabits a wide spectre of different soils types, but most commonly it is found on deep dystric cambisols and on luvisols on silicates.

Beech is the dominant edifying species in the tree layer. However, unlike acidophilic beech forests of the alliance *Luzulo-Fagion*, mixed stands are much more common in this phytocoenosis. In lower areas, there are additions of sessile oak and common hornbeam, and in the higher of sycamore, Norway maple, common maple and wych elm. The shrub layer is often very rich. Apart from the species from the tree layer, there are also *Daphne mezereum, D. laureola, Sambucus racemosa, Ilex aquifolium, Lonicera xylosteum, L. alpigena, Euonymus latifolia* and others. The particularly rich ground layer is characterised by some specific species of Illyrian beech forests (*Lamium orvala, Haquetia epipactis, Epimedium alpinum, Scopolia carniolica, Euphorbia carniolica, Omphalodes verna, Calamintha grandiflora, Dentaria polyphylla, Geranium nodosum* and others), but the species characteristic for the majority of European beech forests often surpass these in terms of coverage and richness. These include *Galium odoratum, Sanicula europaea, Actaea spicata, Carex sylvatica, Pulmonaria officinalis, Anemone nemorosa, Lilium martagon, Mercurialis perennis, Lamiastrum galeobdolon, Mycelis muralis, Dentaria bulbifera, Viola reichenbachiana, Euphorbia amygdaloides, Galium sylvaticum, Fragaria vesca* and others (Table 4).

Unlike many neighbouring and other regions in Central Europe, beech in this region occurs in its natural distribution range. Therefore, it has not been massively destroyed and replaced by spruce and pine cultures. Beech stands in this area have been preserved because this hilly and mountainous region is relatively difficult to reach, and the area has therefore not been given over to settlements, roads, vineyards or agricultural land.

A relict **association of lime and yew (*Tilio-Taxetum* Glavač 1959)** is fragmentarily distributed in the belt of the forest of mountain beech with dead nettle. It exists as a permanent stage on steep limestone blocks that often appear on the surface. Beech, broad-leaved lime, yew and beam-tree dominate a broken tree canopy. Elements of the orders *Fagetalia* and *Quercetalia pubscentis* occur frequently in the shrub and ground layers. Of special interest are the species *Polypodium vulgare, Phyllitis scolopendrium, Valeriana tripteris, Sesleria kalnikensis*, endemic *Iris croatica* and others.

Of basophilic hilly beech forests, special mention should be made of the **forest of beech forest with hop hornbeam (*Ostryo-Fagetum sylvaticae* Wraber /1950/ 1968)**. This is a thermophilic, continental association of beech forests, parallel with littoral beech forest with autumn sesleria (Trinajstić 1972). It grows in sunny positions in the sub-mountainous and mountainous belt on carbonate substrates and basophilic soils, most frequently on mollic leptosols and rendzic leptosols on dolomite. It reaches heights of 700 m and is best represented in the Samobor chain. The tree layer is dominated by beech, but large-sized hop hornbeam, Italian maple, beam-tree and flowering ash are also common. Apart from these species, the shrub layer consists of *Rosa arvensis, Daphne mezereum, Cornus mas* and *Euonymus verrucosa,* while the rich layer of ground vegetation is dominated by basophilic-thermophilic species, such as *Erica carnea, Helleborus macranthus, Buphtalmum salicifolium, Peucedanum oreoselinum*, but also by the species of continental beech forests.

MOUNTAINOUS VEGETATION BELT (ALTIMOUNTAINOUS) GORSKI (ALTIMONTANSKI) VEGETACIJSKI POJAS

In the area of the City of Zagreb and the Zagreb County this vegetation belt is very distinct and simply constructed. It is characterised by beech-fir forests, which occur as low as 500 m on the north side of Mount Medvednica and 800 m on its south side. Apart from these, another important association is the association of sycamore and common ash, which can sometimes be found at higher positions in the lower hilly region.

The forest of beech and fir (*Abieti-Fagetum "pannonicum"* Rauš 1969 prov.). Compared to beech-fir forests in the Dinara region, the beech-fir forests between the Rivers Sava and Drava thrive in conditions of warmer climate, less precipitation, deep dystric soils and silicate substrate in a disjunct area of Ravna Gora, Trakošćan, Macelj, Ivanščica, Strahinjščica, Medvednica and Papuk. Since they continue onto a prominent vegetation belt of mountain beech forests, these forests were managed as even-aged stands due to smaller areas in the major part of the distribution belt. Selection management, which favours mutual relationships and characteristics of the principal tree species - the beech and the fir, has only recently been prescribed in these forests. The floral composition of these forests is relatively poor.

On Medvednica, the association occurs on deep dystric cambisols and illimerised soils over a silicate substrate. The phytocoenosis thrives in all expositions and inclinations, and descends low down in ditches.

The Pannonian beech-fir forests belong to the amphi-Pannonian vegetation zone of the European-altimontane belt, as has already been mentioned.

The edifying species determining the appearance of the association are beech and fir, while other important tree species include *Acer pseudoplatanus, Acer platanoides, Ulmus glabra* and *Fraxinus excelsior*. In the shrub layer the dominant species are *Daphne laureola* and *D. mezereum*, while the ground layer consists of *Athyrium filix femina, Dryopteris filix mas, Dryopteris montana, Polystichum lobatum, Festuca drymeia, Lunaria rediviva, Cardamine enneaphylos, C. savensis, Dentaria bulbifera, Sanicula europaea, Galium odoratum, Actaea spicata, Pulmonaria officinalis, Corydalis cava* and *C. solida* and others.

Medvedović (1990) differentiates two sub-associations in the Pannonia beech-fir forests: *typicum* and *dentarietosum trifoliae* on carbonate rocks and the soils of the calcocambisol type in Croatian Zagorje. Their differentiating species are of basophilic-thermophilic character (*Viburnum lantana, Sorbus aria, Berberis vulgaris, Sorbus torminalis, Cornus mas, Ruscus hypoglossum, Ligustrum vulgare, Lathyrus niger, Melittis melissophyllum, Fraxinus ornus*).

The forest of sycamore and common ash (*Chrysanthemo macrophylli-Aceretum pseudoplatani* /Ht. 1938/ Borh. 1963). The forest association of sycamore and common ash, originally named *Aceri-Fraxinetum excelsioris* (Horvat 1938), occurs in the area of beech-fir forests on Medvednica, in humid and protected valleys in which the soil is richly saturated with large quantities of snow in winter. One of the main ecological properties of the valleys is a long presence of snow on the soil, which leads to increased humidity, but also to a shorter period for micro-organism activity. Such conditions are conducive to the formation of deep humus-accumulative soil horizon, because the production of organic matter exceeds its dissolution. This is the reason why the phytocoenosis is characterised by numerous nitrophilic species, of which *Lunaria rediviva* is particularly important.

The tree layer is dominated by precious broad-leaved species of sycamore (*Acer pseudoplatanus*), common ash (*Fraxinus excelsior*), and frequently wych elm (*Ulmus glabra*). Other species from adjacent beech-fir forests are also common, among which the Norway maple (*Acer platanoides*) is particularly prominent. The shrub layer is completely dominated by red-berried elder (*Sambucus racemosa*), with the presence of mezereon and spurge laurel (*Daphne mezereum* and *D. laureola*), fly honeysuckle (*Lonicera xylosteum*) and broad-leaved spindle tree (*Euonymus latifolius*).

The luscious and species-rich layer of ground vegetation is dominated by nitrophilic species. The following species are of particular significance as indicators of the association: *Lunaria rediviva, Senecio nemorensis, Chrysanthemum macrophyllum, Geranium pheum, Corydalis cava, C. solida* and *Telekia speciosa*. Phytocoenological recordings from Mount Medvednica reveal frequent presence of *Galium odoratum, Dentaria bulbifera, Cardamine trifolia, C. enneaphyllos, Leucoium vernum, Aruncus dioicus, Athyrium filix femina, Dryopteris filix mas, Circaea lutetiana, Petasites albus, Petasites niveus, Petasites hybrida, Chaerophyllum sylvaticum, Actaea spicata, Phyllitis scolopendrium* and others.

Although of a relatively modest distribution range, this association is economically very important, primarily due to the growth of relatively rare and valuable species such as sycamore, common ash, Norway maple and wych elm.

Table 4. The forest associations with beech
Tablica 4. Šumske zajednice s bukvom

Association:		*Luzulo-Fagetum sylvaticae* Mausel 1937		*Lamio orvalae-Fagetum sylvaticae* Ht. 1938		*Abieti-Fagetum "pannonicum"* Rauš 1969 prov.
Area:		Vukomeričke g.	Samoborsko g.	Medvednica	Vukomeričke g.	Medvednica
Number of recordings:		11	14	10	18	30
Plot size (m^2):		100-500	100-200	400	100-500	400
FLORAL COMPOSITION						
Characteristic and distinguishing species of the association *(Luzulo-Fagetum)* and alliance *(Luzulo-Fagion)*:						
Pteridium aquilinum (L.) Kuhn.	B	V	.	.	II	.
Juniperus communis L.		II	.	.	.	.
Luzula luzuloides (Lam.) D. W.	C	V	V	III	II	III
Pteridium aquilinum (L.) Kuhn.		III	V	.	I	I

Hieracium umbellatum L.	IV	I	.	.	I
Vaccinium myrtillus L.	.	V	I	.	.
Melampyrum pratense L.	V	IV	II	II	.
Veronica officinalis L.	IV	I	I	.	.
Hieracium racemosum W.K.	V	II	I	III	.
Genista germanica L.	IV	.	.	.	
Genista tinctoria L.	III	I	.	.	.
Calluna vulgaris (L.) Hull.	II	III	.	.	.
Polytrichum attenuatum Menz. D	V	V	.	III	.
Leucobrium glaucum(L.) Schpr.	V		.	.	.
Characteristic and distinguishing species of the associations (*Lamio orvalae-Fagetum* and *Abieti-Fagetum*) and alliance (*Aremonio-Fagion*):					
Daphne laureola L. B	.	.	.	.	I
Ruscus hypoglossum L.	.	II	I	.	.
Dentaria trifolia W. K. C	.	.	.	III	II
Dentaria enneaphyllos L.	.	.	I	.	III
Cyclamen purpurascens L.	.	.	.	.	IV
Hacquetia epipactis (Scop.) D.C.	.	.	I	.	I
Calamintha grandiflora (L.) Mch.	.	.	.	.	I
Festuca drymeia M. K.	.	.	.	.	III
Mercurialis perennis L.	.	.	II	.	.
Ruscus hypoglossum L.	.	.	.	V	I
Lamium orvala L.	.	.	II	.	I
Aposeris foetida (L.) Less.	.	II	.	IV	I
Primula vulgaris Huds.	.	.	.	.	I
Knautia drymeia Heuff.	.	.	.	I	I
Vicia orobides Wulf.	.	.	II	.	.
Cardamine trifolia L.	.	.	IV	.	II
Stellaria holostea L.	.	.	.	III	.
Epimedium alpinum L.	.	.	.	I	.
Cardamine polyphylla (W.K.) Schulz.	.	.	II	.	.
Characteristic species of order (*Fagetalia sylvaticae*):					
Fagus sylvatica L. A	V	V	V	V	V
Acer pseudoplatanus L.	.	.	I	I	I
Acer platanoides L.	.	.	III	.	I
Fraxinus excelsior L.	.	.	I		I
Fagus sylvatica L. B	V	V	IV	V	III
Acer pseudoplatanus L.	.	.	I	II	III
Sambucus racemosa L.	.	.	.	.	II
Daphne mezereum L.	.	.	I	I	I
Ulmus glabra Huds.	.	.	I	.	I
Fraxinus excelsior L.	.	.	I	.	I
Acer platanoides L.	.	.	I	.	II
Athyrium filix femina (L.) Roth. C	II	I	II	III	IV
Dryopteris filix mas (L.) Schott.	II	.	IV	IV	V
Galium odoratum (L.) Scop.	II	I	V	V	V
Senecio nemorensis L.	.	.	III	.	V
Acer pseudoplatanus L.	.	.	III	I	IV
Mycelis muralis (L.) Rchb.	IV	.	II	IV	IV
Sanicula europaea L.	II	II	II	V	.

Brachypodium sylvaticum (Huds.) L.S.	III	I	I	I	I
Fagus sylvatica L.	IV	II	I	III	.
Carex sylvatica Huds.	IV	.	.	V	II
Lamiastrum galeobdolon (L.) E.P.	.	.	.	IV	IV
Dentaria bulbifera L.	.	.	I	IV	IV
Polystichum aculeatum (L.) Roth.	.	.	.	.	I
Pulmonaria officinalis L.	.	.	IV	.	I
Salvia glutinosa L.	.	.	I	II	I
Prenanthes purpurea L.	.	IV	I	.	II
Euphorbia amygdaloides L.	.	.	.	I	I
Viola reichenbachiana Jord.	.	.	I	IV	III
Paris quadrifolia L.	.	.	I	.	I
Scrophularia nodosa L.	.	.	I	.	III
Phyllitis scolopendrium (L.) Newm.	.	.	.	.	I
Polygonatum multiflorum (L.) All.	.	.	I	II	.
Actaea spicata L.	.	.	II	.	.
Symphytum tuberosum L.	.	.	II	I	I
Lunaria rediviva L.	.	.	I	.	III
Asarum europaeum L.	.	.	I	IV	I
Glechoma hirsuta W.K.	.	.	I	.	III
Campanula trachelium L.	.	.	I	I	I
Ranunculus lanuginosus L.	.	.	.	II	II
Geranium robertianum L.	.	.	.	.	I
Acer plataniodes L.	.	.	II	.	III
Melica nutans L.	.	.	.	.	I
Sambucus racemosa L.	.	.	.	.	I
Fraxinus excelsior L.	.	.	I	.	I
Arum maculatum L.	.	.	I	.	I
Polystichum lonchitis (L.) Roth.	.	.	.	.	II
Aruncus sylvestris Kostel	.	.	.	.	I
Alliaria petiolata Andrz.	.	.	II	.	I
Neottia nidus avis (L.) L.C. Rich	.	.	.	II	.
Ulmus glabra Huds.	.	.	I	.	.
Cyclamen europaeum L.	.	.	III	II	.
Euphorbia dulcis L.	.	.	I	II	.
Polygonatum odoratum (Mill.) Dr.	.	.	.	II	.
Characteristic species of class (*Querco-Fagetea*):					
Carpinus betulus L. A	I	I	I	III	II
Acer campestre L.	.	.	.	I	.
Tilia cordata Mill.	.	.	.	I	.
Corylus avellana L.	.	.	.	I	.
Quercus cerris L.	I		.	I	.
Carpinus betulus L. B	I	II	II	III	I
Sorbus torminalis (L.) Cr.	I	III	.	I	.
Corylus avellana L.	.	.	III	I	III
Prunus avium L.	I	.	I	.	I
Acer campestre L.	.	.	.	II	.
Crataegus monogyna Jacq.	II	.	.	II	.
Pyrus pyraster (L.) Borkh.	I	.	.	II	.
Crataegus oxyacantha L.	.	.	.	I	.
Rubus caesius L.	.	.	.	I	.

Ligustrum vulgare L.	.	.	.	I	.
Cornus sanquinea L.	I	.	.	I	.
Lonicera caprifolium L.	.	.	.	I	.
Tilia cordata Mill.	.	.	.	I	.
Chamaecytisus hirsutus (L.) Lk.	I		.	.	.
Carpinus betulus L. C	II	I	.	II	I
Hedera helix L.	.	I	V	III	III
Anemone nemorosa L.	.	.	III	.	III
Circaea lutetiana L.	.	.	III	III	I
Melittis melissophyllum L.	.	.	.	I	I
Lathyrus vernus (L.) Bernh.	.	.	I	III	.
Prunella vulgaris L.	III	.	.	III	.
Chamaecytisus hirsutus (L.) Lk.	II	.	.	I	.
Moehringia trinervia (L.) Clairv.	.	.	.	.	II
Corydalis cava (L.) Schw. K.	.	.	.	.	II
Clematis vitalba L.	.	.	.	I	I
Aegopodium podagraria L.	.	.	.	.	I
Platanthera bifolia (L.) L.C. Rich.	.	.	I	II	.
Geum urbanum L.	.	.	I	.	.
Prunus avium L.	.	I	.	II	.
Galium vernum Scop.	.	.	.	III	.
Tamus communis L.	.	.	I	II	.
Sorbus torminalis (L.) Cr.	.	.	.	II	.
Lonicera caprifolium L.	.	.	.	II	.
Acer campestre L.	.	I	.	I	.
Convallaria majalis L.	.	II	.	I	I
Tilia cordata Mill.	.	.	.	I	.
Lathyrus venetus (L.) Wohlf.	.	.	.	I	.
Lycopus europaeus L.	.	.	.	I	.
Cerastium sylvaticum W.K.	.	.	.	I	.
Cynanchum vincetoxicum (L.) Pers.	.	.	.	I	.
Cephalanthera rubra (L.) L.C. Rich.	.	.	.	I	.
Carex remota L.	.	.	.	I	.
Cornus sanquinea L.	.	.	.	I	.
Lonicera xylosteum L.	.	.	.	I	.
Festuca altissima All.	.	.	.	I	.
Other species:					
Quercus petraea Lieb. A	III	V	IV	V	I
Castanea sativa Mill.	II	IV	I	I	I
Abies alba Mill.	.	.	III	.	V
Populus tremula L.	I	.	.	.	.
Alnus glutinosa (L.) Gaertn.	.	.	.	I	.
Fraxinus ornus L.	.	II	.	.	.
Castanea sativa Mill. B	III	V	I	I	I
Rubus sp.	IV	II	.	III	V
Abies alba Mill.	.	.	V	.	V
Quercus petraea Lieb.	I	III	.	I	.
Rubus idaeus L.	.	.	.	.	III
Sambucus nigra L.	.	.	III	.	.
Frangula alnus L.	I	II	.	.	.
Rosa arvensis Huds.	.	.	.	I	.

Hieracium sylvaticum L. C	II	III	II	I	I
Quercus petraea Lieb.	IV	III	.	V	I
Gentiana asclepiadea L.	II	II	.	II	I
Doronicum austriacum Jacq.	III	I	I	.	II
Abies alba Mill.	.	.	I	.	V
Fragaria vesca L.	III	.	.	II	III
Oxalis acetosella L.	.	.	.	II	III
Rubus sp.	.	.	III	I	I
Galium sylvaticum L.	.	III	I	II	I
Castanea sativa Mill.	I	II	II	.	I
Polypodium vulgare L.	II	.	.	.	I
Festuca gigantea (L.) Vill.	.	.	.	.	I
Maianthemum bifolium (L.) Schm.	.	.	.	.	I
Galium rotundifolium L.	.	.	.	.	I
Galeopsis speciosa Mill.	II		I	II	.
Dryopteris dilatata (Hoffm.) A. Gray	.	.	.	.	II
Petasites albus Gartn.	.	.	II	.	II
Galeopsis pubescens Bess.	II	I	I	.	.
Solidago virga aurea L.	.	II	.	.	II
Urtica dioica L.	.	.	I	.	II
Solanum dulcamara L.	.	.	.	.	I
Glechoma hederacea L.	.	.	.	I	.
Eupatorium cannabinum L.	.	.	I	.	I
Carex pilosa Scop.	.	.	.	.	I
Geranium phaeum L.	.	.	II	.	II
Calamagrostis arundinacea (L.) Roth.	.	I	.	.	.
Polygonatum verticillatum (L.) All.	.	.	II	.	.
Potentilla micrantha Ram.	.	.	II	.	.
Aruncus sylvestris Kostel.	.	I	II	.	.
Carex maxima Huds.	.	.	II	.	.
Cephalantera alba (Cr.) Simk.	.	.	I	.	.
Primula sp.	.	.	I	.	.
Staphylea pinnata L.	.	I	I	I	.
Siler trilobium (L.) Cr.	.	.	I	.	.
Melandrium rubrum (Schk.) Roehl.	.	.	I	.	.
Lycopodium sp.	.	.	I	.	.
Juncus effusus L.	.	.	I	I	.
Carex humilis Leyss.	.	.	I	.	.
Sambucus nigra L.	.	.	I	.	.
Veronica montana L.	.	.	I	.	.
Cephalantera longifolia (L.) Fritsch	.	.	I	.	.
Hypericum montanum L.	II	.	.	.	.
Potentilla erecta (L.) Raeusch.	II	.	.	.	.
Molinia litoralis Host	.	II	.	.	.
Melampyrum silvaticum L.	.	I	.	.	.
Serratula tinctoria L.	.	II	.	.	.
Fraxinus ornus L.	.	I	.	.	.
Tussilago farfara L.	.	I	.	.	.

Explanation of abbrevations: A - Tree layer, B - Shrub layer, C - Ground vegetation layer, D - Moss layer, I - V - Degree of participation

THE PHYTOCOENOLOGICAL MAP OF THE STUDIED AREA
FITOCENOLOŠKA KARTA ISTRAŽIVANOG PODRUČJA

To draw up a phytocoenological map of the forests in the City of Zagreb and the Zagreb County, printed and hand-written maps have been used (Baričević and Vukelić 1997, Pelcer *et al.* 1976 - 1982, Rauš 1980 and 1993, Rauš and Vukelić 1996, Trinajstić *et al.* 1992, Vukelić 1990), as well as documentation from the Forest Management Service in the Public Enterprise "Croatian Forests". As these maps are in much larger scales, it has not been possible to include all details and units.

The enclosed phytocoenological map is a good illustration of the diversity and wealth of the forest vegetation. The vertical distribution of forest associations, encompassing the amplitude of 1,000 m and ranging from the banks of rivers to the top of Medvednica, is particularly vivid. Forest associations in state forests have been accurately and reliably defined since they have been studied in detail. The same could not be done consistently for private forests because some of them have never been mapped. This refers primarily to Croatian Zagorje, the northern part of the Samobor chain, and a smaller part of Jastrebarsko and Vrbovec areas. The forest associations in these areas have been clearly identified for the purpose of this study and the accuracy of the phytocoenological identification is unquestionable. However, a more precise spatial demarcation should be conducted in some future phytocoenological research.

A relatively similar problem relates to the demarcation of certain associations dominated by one species, such as beech, for example. Three beech associations have been included in one cartographic unit (*Luzulo-Fagetum, Lamio orvalae-Fagetum* and *Ostryo-Fagetum*), because they have not been spatially defined so far. However, such deviations do not influence the validity of the survey, because the descriptions are detailed enough to indicate specific properties and differences among certain vegetation units. Moreover, the material needed for making this study is complemented with original phytocoenological recordings.

We should also point out that forest cultures over larger areas are marked only with signs, because they, as for example locust trees in private forests of the Vrbovec-Zelina area, dominate the entire area, but in separate fragments of several acres to several hectares.

The phytocoenological map contains not only the descriptions of forest associations and research documentation, but represents a very valuable basis for the assessment of the forest fund from the standpoint of biological and genetic diversity, and provides a starting point for planning in forestry and other interventions in this region.

CONCLUSIONS
ZAKLJUČCI

Forest vegetation in the studied area was studied in depth relatively early. It is composed of about 20 basic associations distributed in four vegetation belts. A major part of the continental associations of Croatia with highly diverse and rich floral composition is represented here. Their systematic position is as follows:

Salicetea purpureae Moor 1958
Salicetalia purpureae Moor 1958
Salicion albae Soó 1940
Salicetum purpureae Wendl.-Zel. 1952
Galio-Salicetum albae Rauš 1973
Salici albae-Populetum nigrae Tx. 1931
Alnetea glutinosae Br.-Bl. Et Tx. 1943
Alnetalia glutinosae Tx. 1937
Alnion glutinosae Malcuit 1929
Frangulo-Alnetum glutinosae Rauš 1968
Leucoio-Fraxinetum angustifoliae Glavač 1959
Alno-Quercion roboris Ht. (1937) 1938
Genisto elatae-Quercetum roboris Ht. 1938
Querco-Fagetea Br.-Bl. et Vlieger 1937
Quercetalia pubescentis Br.-Bl. (1931) 1932
Ostryo-Carpinion orientalis Ht. (1954) 1958
Ostryo-Quercetum pubescentis Ht.1938
Quercion pubescentis-petraeae Br.-Bl. 1931
Lathyro-Quercetum petraeae Ht. (1938) 1958
Quercetalia robori-petraeae Tx. 1937.
Castaneo-Quercion petraeae (Soó 1962) Vukelić 1990
Querco-Castaneetum sativae Ht. 1938
Hieracio racemosi-Quercetum petraeae Vukelić (1990) 1991
Fagetalia sylvaticae Pawl. 1928
Carpinion betuli Isll. 1932
Carpino betuli-Quercetum roboris (Anić 1959) Rauš 1969
Epimedio-Carpinetum betuli (Ht. 1938) Borhidi 1963
Luzulo-Fagion Lohm. et. Tx. 1954
Luzulo-Fagetum sylvaticae Meusel 1937
Aremonio-Fagion (Ht. 1938) Törek *et al.* 1989
Lamio orvalae-Fagetum sylvaticae Ht. 1938
Abieti-Fagetum "pannonicum" Rauš 1969 prov.
Chrysanthemo macrophylli-Aceretum pseudoplatani (Ht. 1938) Borh. 1963
Ostryo-Fagetum sylvaticae Wraber (1950) 1958
Tilio-Taxetum Glavač 1959

The riparian vegetation, whose major part consists of forests of willows and poplars (*Salici-Populetum s.l.*), is developed in the lowland or planar belt along the banks of rivers. However, the forests in this belt were cleared in the past to make way for agricultural land. In the depressions of the lowland belt the principal edifying species are the pedunculate oak, narrow-leaved ash, black alder, lowland elm and spreading elm. The growth of these associations is closely related to the relatively high level of groundwater, whose drop, caused by ameliorative treatments, has led to the dieback of forests, such as for example in Turopoljski Lug, Žutica and elsewhere. On the other hand, excessive bogging of the biotop with stagnant surface water is equally harmful. The basic associations of these humid biotops are the forest of pedunculate oak with great green weed *(Genisto elatae-Quercetum roboris)*, narrow-leaved ash with autumn snowflake (*Leucoio-Fraxinetum angustifoliae*) and black alder with buckthorn (*Frangulo-Alnetum glutinosae*). The third type of the association of the lowland region are forests of pedunculate oak with common hornbeam (*Carpino betuli-Quercetum roboris*) on micro-elevations (lowland pseudogley) with lower levels of groundwater and no floods.

The belt of lower hills extends from 150 to 400 (500) m above sea level, and is represented by the edges of Medvednica, the hills of Žumberak and Samobor, Vukomeričke Gorice and elsewhere. The basic association is the forest of sessile oak and common hornbeam (*Epimedio-Carpinetum betuli*), whose composition contains some of the species from the Illyrian floral element, which places them among the richest in Europe. Apart from them, acidophilic forests of sessile oak and sweet chestnut (*Querco-Castaneetum sativae*), acido-thermophilic forests of sessile oak and hawkweed (*Hieracio racemosi-Quercetum petraeae*) and thermophilic forest associations of sessile oak and black pea (*Lathyro-Quercetum petraeae*) and pubescent oak with hop hornbeam (*Ostryo-Quercetum pubescentis*) are also significant.

The belt of higher hills (400 - 800 m above sea level) is characterised by the most represented tree species in Croatia - the common beech. It occurs in the well-known Illyrian association with dead nettle (*Lamio orvalae-Fagetum sylvaticae*), in the acidophilic forest with woodrush (*Luzulo-Fagetum sylvaticae*), and in the thermophilic-basophilic association with hop hornbeam (*Ostryo-Fagetum sylvaticae*). The relict forest of lime and yew (*Tilio-Taxetum*) is of particular importance due to its rarity and natural-scientific characteristics.

The mountain belt (above 700 - 800 m above the sea) is dominated by the forest association of beech and fir (*Abieti-Fagetum s.l.*), similar to that in the Dinara region of Croatia. It is distributed only on Medvednica and has prominent economic and protective functions. The forest of sycamore and common ash (*Chrysanthemo macrophylli-Aceretum pseudoplatani*) also occurs sporadically.

The studied forest associations have a natural composition and contain a relatively large number of species, of which those of the Illyrian and south-east European character are particularly prominent. The western part of the studied area is much more indented in terms of the relief and is richer in forests and forest associations. The eastern part contains half the amount of forests, but their economic and ecological value is outstanding. The south-east part of Zagreb (especially the part along the course of the River Sava) is very poor in forests, and should be afforested in the future given the importance of forests in regulating the water regime.

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ŠUMSKA VEGETACIJA GRADA ZAGREBA I ZAGREBAČKE ŽUPANIJE

SAŽETAK

U radu su prikazani rezultati fitocenoloških istraživanja šumske vegetacije Grada Zagreba i Zagrebačke županije. Grad Zagreb i Zagrebačka županija nalaze se u zapadnom, najgušće naseljenom području Hrvatske. Unatoč vrlo ranoj naseljenosti, relativno brzom i značajnom industrijskom, infrastrukturnom i svakom drugom razvitku, šume se prostiru na 143000 ha ili na gotovo 40 % istraživanoga područja. One su uvelike sačuvale prirodan sastav i strukturu pa su vrlo pogodne za fitocenološka istraživanja, pogotovo što ovo područje vrlo dobro predstavlja vertikalno zoniranje šumske vegetacije jugozapadnoga dijela Panonske ravnice s mnogim predalpskim florno-genetskim obilježjima kakva se nastavljaju u susjednoj Sloveniji. Visinska razlika istraživanih šumskih zajednica iznosi nešto manje od tisuću metara (od 120 do 1 033 m n.v.) pa su šumske zajednice bogate i raznolike u flornom sastavu.

Prikaz šumske vegetacije dan je po visinskim pojasima. U nizinskom pojasu od 80 do 150 m nadmorske visine temeljno obilježje geološko-litološkoj i pedološkoj građi, kao i vegetacijskoj slici daju riječni tokovi Save, Lonje, Česme, Kupe i brojni manji vodotoci koji su većinom meliorirani. Brežuljkasti pojas od 150 do 400 (500) metara, brdski od 400 do 800 i gorski iznad 800 m nadmorske visine vrlo su različitih pedoloških i klimatskih uvjeta pa fitocenološki sastav pokazuje jasno vertikalno zoniranje, u kojem su glavne vrste hrast kitnjak, iznad njega u brdskom pojasu obična bukva, a u gorskom bukva i jela. Različite litološke podloge uvjetuju velik broj šumskih zajednica koje pripadaju različitim sintaksonomskim kategorijama.

Šumska vegetacija na istraživanom području relativno je rano i dobro istražena. Mi smo je istraživali u posljednje četiri godine, no obilno smo se služili fitocenološko, literaturom i drugih autora, u prvom redu Anića (1940), Cestara i dr. (1978–1982), Glavača (1958. i 1959), Rauša (1969. i 1996), Rauša i dr. (1992), Rauša i Vukelića (1993), Šegulje (1974), Šugara (1972) i Vukelića (1991).

Dvadeset temeljnih šumskih zajednica svrstano je u sedam sveza, tri reda i dva razreda, što smo samo djelomice prikazali u četiri fitocenološke tablice.

Uz prikaz je izrađena fitocenološka karta mjerila 1:100000 s 13 najvažnijih fitocenoza. Razlog je tomu što neke zajednice dolaze fragmentarno na vrlo malim površinama (različite ritske zajednice, šume plemenitih listača) ili se zbog razvijene orografije terena i promjene sinekoloških uvjeta intenzivno miješaju, pa ih u mjerilu 1:100000 nije moguće prikazati i točno odrediti. Karta zbog formata nije mogla biti tiskana uz rad i nalazi se u arhivu Zavoda za uzgajanje šuma, Šumarskoga fakulteta Sveučilišta u Zagrebu.

Može se ustvrditi da se na istraživanome području prostire velik dio kontinentalnih zajednica Hrvatske te da su raznolikoga i bujnoga flornoga sastava. Njihov sistematski položaj je sljedeći:

Salicetea purpureae Moor 1958
- *Salicetalia purpureae* Moor 1958
  - *Salicion albae* Soó 1940
    - *Salicetum purpureae* Wendl.-Zel. 1952
    - *Galio-Salicetum albae* Rauš 1973
    - *Salici albae-Populetum nigrae* Tx. 1931

Alnetea glutinosae Br.-Bl. et Tx. 1943
- *Alnetalia glutinosae* Tx. 1937
  - *Alnion glutinosae* Malcuit 1929
    - *Frangulo-Alnetum glutinosae* Rauš 1968
    - *Leucoio-Fraxinetum angustifoliae* Glavač 1959
  - *Alno-Quercion roboris* Ht. (1937) 1938
    - *Genisto elatae-Quercetum roboris* Ht. 1938

Querco-Fagetea Br.-Bl. et Vlieger 1937
- *Quercetalia pubescentis* Br.-Bl. (1931) 1932
  - *Ostryo-Carpinion orientalis* Ht. (1954) 1958
    - *Ostryo-Quercetum pubescentis* Ht.1938
  - *Quercion pubescentis-petraeae* Br.-Bl. 1931
    - *Lathyro-Quercetum petraeae* Ht. (1938) 1958
- *Quercetalia robori-petraeae* Tx. 1937
  - *Castaneo-Quercion petraeae* (Soó 1962) Vukelić 1990
    - *Querco-Castaneetum sativae* Ht. 1938
    - *Hieracio racemosi-Quercetum petraeae* Vukelić (1990) 1991
- *Fagetalia sylvaticae* Pawl. 1928
  - *Carpinion betuli* Isll. 1932
    - *Carpino betuli-Quercetum roboris* (Anić 1959) Rauš 1969
    - *Epimedio-Carpinetum betuli* (Ht. 1938) Borhidi 1963
  - *Luzulo-Fagion* Lohm. et Tx. 1954
    - *Luzulo-Fagetum sylvaticae* Meusel 1937

Aremonio-Fagion (Ht. 1938) Törek *et al.* 1989
Lamio orvalae-Fagetum sylvaticae Ht. 1938
Abieti-Fagetum "pannonicum" Rauš 1969 prov.
Chrysanthemo macrophylli-Aceretum pseudoplatani (Ht. 1938) Borh. 1963
Ostryo-Fagetum sylvaticae Wraber (1950) 1958
Tilio-Taxetum Glavač 1959

U nizinskom ili planarnom pojasu uz korita rijeka razvijena je ritska vegetacija čiji glavni dio čine vrbove i topolove šime (*Salici-Populetum s. l.*). No, u tom su pojasu šume u prošlosti iskrčene, a tlo privedeno poljoprivrednoj proizvodnji. U udubinama i nizama nizinskoga pojasa glavne su edifikatorske vrste hrast lužnjak, poljski jasen, crna joha, nizinski brijest i vez. Pridolazak tih zajednica u uskoj je vezi s relativno visokom razinom podzemnih voda čije spuštanje zbog meliorativnih zahvata izaziva sušenje šumskih sastojina, na primjer u Turopoljskom lugu, Žutici i drugdje. S druge strane, jednako je opasno i prekomjerno zamočvarenje biotopa zastojnom površinskom vodom. Temeljne su zajednice tih vlažnih staništa šuma hrasta lužnjaka s velikom žutilovkom (*Genisto elatae-Quercetum roboris*), poljskoga jasena s kasnim drijemovcem (*Leucoio-Fraxinetum angustifoliae*) i crne johe s trušljikom (*Frangulo-Alnetum glutinosae*). Treći tip zajednica nizinskoga područja su šume hrasta lužnjaka i običnoga graba (*Carpino betuli-Quercetum roboris*) na gredama (nizinski pseudoglej) s nižom razinom podzemnih voda i bez poplava.

Brežuljkasti ili kolinski vegetacijski pojas prostire se na rubovima Medvednice, Žumberačkoga i Samoborskoga gorja, u Vukomeričkim goricama i drugdje. Temeljna je zajednica šuma hrasta kitnjaka i običnoga graba (*Epimedio-Carpinetum betuli*), u čijem se sastavu nalaze neke vrste ilirskoga flornoga elementa, što ih svrstava među najbogatije u Europi. Uz njih su značajne acidofilne šume hrasta kitnjaka i običnoga kestena (*Querco-Castaneetum*), acidotermofilne šume hrasta kitnjaka s runjikom (*Hieracio racemosi-Quercetum petraeae*) te termofilne šumske zajednice hrasta kitnjaka i crnoga grahora (*Lathyro-Quercetum petraeae*) i hrasta medunca s crnim grabom (*Ostryo-Quercetum pubescentis*).

Brdski ili montanski pojas obilježava najproširenija vrsta drveća u Hrvatskoj – obična bukva, i to u poznatoj ilirskoj zajednici s mrtvom koprivom (*Lamio orvalae-Fagetum sylvaticae*), u acidofilnoj šumi s bekicom (*Luzulo-Fagetum sylvaticae*) i u termofilno-bazafilnoj zajednici s crnim grabom (*Ostryo-Fagetum sylvaticae*). Po rijetkosti i prirodoznanstvenoj zanimljivosti na Medvednici se ističe reliktna šuma lipe i tise (*Tilio-Taxetum*).

U gorskom ili altimontanskom pojasu prevladava bukovo-jelova šumska zajednica (*Abieti-Fagetum s.l.*), slična onoj u Dinaridima Hrvatske. Rasprostire se samo na Medvednici i istaknute je gospodarske i zaštitne funkcije. Uz nju sporadično pridolazi šuma gorskoga javora i običnoga jasena (*Chrysanthemo macrophylli-Aceretum pseudoplatani*).

Istražene šumske zajednice prirodnoga su sastava, s relativno velikim brojem vrsta u kojima se ističu vrste ilirskoga i jugoistočnoeuropskoga karaktera. Zapadni,

reljefno mnogo razvedeniji dio istraživanoga područja bogatiji je šumama i šumskim zajednicama. U istočnom dijelu dvostruko je manje šuma, no one su gospodarski i ekološki iznimno vrijedne. Šumama je vrlo siromašno područje jugoistočno od Zagreba (poglavito uz savski tok), pa će ga u budućnosti trebati pošumiti zbog velikoga značenja šuma u reguliranju vodnoga režima.

Ključne riječi: šumska vegetacija, florna struktura, Grad Zagreb, Zagrebačka županija

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SOILS OF FOREST ECOSYSTEMS IN THE ZAGREB COUNTY

TLA ŠUMSKIH EKOSUSTAVA ZAGREBAČKE ŽUPANIJE

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The Zagreb County is situated in the west part of central Croatia. Together with the city of Zagreb it covers the surface of 3.720 km^2, that is approx. 6,6% of the territory of the Republic of Croatia. The surface under forests and forest land is 1.560 km^2, that is about 43% of the County surface.

In the constelation of pedogenetic factors, the characteristics of forest ecosystem pedosphere in the Zagreb County are based on the physiographic properties of the following soils:

1. rendzic leptosol
2. dystric cambisol
3. calci-mollic cambisol
4. luvisol
5. planosol
6. gleysol.

In combination with these soils, as secondary units and inclusions, there occur also: regosol, rendzic-lithic leptosol, dystric leptosol, eutric cambisol, fluvisol, humic fluvisol and gleyic planosol.

In the spatial division of forest pedosphere of the County, 5 mapping units comprising the largest forest complexes are distinguished in particular. These are:

1. mapping unit with the soils on carbonate substrata of Žumberak and Medvednica
2. mapping unit with luvisols and planosols of Vukomeričke gorice
3. mapping unit with prevailing planosols of piedmont regions and hills
4. mapping unit with gleysols of the Kupa basin, Turopoljski lug, Varoški lug and Lonjsko polje
5. mapping unit with dystric cambisols on metamorphites of Medvednica.

These 5 mapping units cover more than 63% of the County forests and are bearers of basic characteristics of the complete forest ecosystem pedosphere.

Key words: Zagreb county, soil, pedosphere

INTRODUCTION
UVOD

The Zagreb County is situated in the western part of central Croatia. Together with the city of Zagreb it covers an area of 3.720 km^2, that is approximately 6,6% of the territory of the Republic of Croatia. Forests and forest land cover 1.560 km^2, or approximately 42% of the total surface of the County1. Such high percentage of forest area as well as the fact that one third of the population of Croatia lives in this County indicate the importance of forest ecosystems for the County. For stable forest ecoystems a very important feature is multifunctionality of soil. The soil is a key ecological niche of forests, which by its production, protective and infrastructural roles is bearer of forest multifunctionality, and so is for most forests in the region of this County, too.

The first scientific researches of features of soils in this region, including conditions of their origin and development, date from the 19^{th} century and refer to farmland. The first more intensive researches of forest ecosystem soils are the works of Gračanin (1939, 1941, 1948, 1960), Kovačević et al. (1963), Martinović (1975), Mayer (1976) and Vranković (1973). The most extensive pedological researches in Croatia refer to the preparation of the national soil map. In the period from 1960 to 1985, the whole of the County area was analyzed and mapped in scale 1:50 000. The Zagreb County is covered by 18 sheets of soil map. The results of this inventory of soils - i.e. the sheets of soil map with explanations and monography of soils of the upper Posavina (Kovačević et al. 1972) - make the basis of this paper in the analysis of physiographic properties and geographical features of forest soils.

FEATURES OF SOIL GENESIS
ZNAČAJKE GENEZE TLA

The pedogenetic factor (the factor of formation - origin and development - of soils) is a substance, force, condition or relationship, or a combination thereof, that acts, has acted or can act on the soil parent material and/or on the soil in the direction of its change (Buol et al. 1980).

According to the actual understanding of soil genesis, the pedogenetic factors are: parent material, climate, relief and organisms, and their main sources are: lithosphere, atmosphere, hydrosphere and biosphere.

Sizes of areas given in this work have been determined by digitalization of the available cartographic materials, namely of the topographic map in scale 1:25 000, from which the forest countours were taken, and of the Basic Pedological Map of the Republic of Croatia in scale 1:50 000.

PARENT MATERIAL
MATIČNI SUPSTRAT

In terms of lithology, the region of the city of Zagreb and the Zagreb County is of a very complex and distinctly heterogenous structure. Distribution of forests being chiefly in a mosaic-like form, the characteristics of parent material are described here for the entire

County, and the main data source is the basic geological map of this area (Basch 1983, Pikija 1987, Šikić et al. 1978). In this area, 5 geomorphological and lithological complexes with a large number of lithological units can be distinguished, namely :

I. Medvednica
II. Flatland and hilly area of the left Sava riverside
III. Alluvial Sava valley
IV. Samoborsko gorje and Žumberak
V. Plešivica piedmont region and Vukomeričke gorice with the central hilly area and the Kupčina basin.

Such division, however, corresponds only partly with the geological or geotecktonical characteristics of the region, but in terms of the pedogenetics, it establishes the best relationship between the parent material, vegetation and relief.

Medvednica mountain
Medvednica

The basic, central ridge of Medvednica is built of metamorphosed diabases and gabbros, and, to a larger extent, of the low level metamorphism schists known as the representatives of green schist facies (Velić, 1994). They show a great variety of structure. Thus, for instance, there were found clay schists, quartz-sericite-clay schists, calci-quartz schists, quartzites, marbles and phyllites. On the surface they are quite crumbly, especially varieties with clay (tendency to swell). On these rocks, dominant soil units are dystric cambisols and dystric leptosols.

On the north-east Medvednica, generally the metamorphosed carbonates as well as the quartz-sericite and quartz-chlorite schists are distinguished.

The west and south-west parts of Medvednica are of extremely complex structure. On the north-west mountainsides there is a group of sediments with sandstones, siltites, as well as limestones and dolomites with sporadically marked bedding (thin bedded micaceous sandstones and flaky marly limestones). The west and south-west Medvednica, in general, is predominantly of calcareous-dolomitic structure.

The southern slopes of Medvednica, from Podsused to Šestine, Markuševec and Čučerje is a variable width zone of various sedimentation products, such as breccias, conglomerates, marls, clays and limestones. Southwardly, this zone is continued by marls, clays and sands. The southernmost and south-east slopes of

Medvednica are built of the so-called slope and terrace sediments: loams, clays, sands and gravels, in frequent mutual alternations (Šikić et al. 1978).

Flatland and Hilly Region of the Sava Left Riverside
Ravničarsko i brežuljkasto područje lijevoga savskoga zaobalja

1. The Upper Pontic sands, marls and clays of the south-east slopes of Medvenica extend in the form of a wide belt from Remete to the east and north-east, as far as to the Lonja River valley. A typical enclave of such sediments is Štakorovečki brijeg, too. The most often they include also larger or smaller amounts of silt size particles, so there are transitions toward silty sands, sandy silts and finally silts with the sand component of as low as 15%.

2. The terrestral carbonate-free loess is a typical sediment of the northern part of this complex. It is mosaically criss-crossed by alluvial, moor argillaceous and argillo-silty, and deluvial-proluvial sedimentary materials.

The terrestrial loess deposits have been preserved on the lowest south-east slopes of Medvednica, from the northern part of the Zagreb urban area in the west to Zelina and Šalovec in the north-east. They lie on morphological elevations near Dugo Selo, Glavničica and Štakorovec. The soil types predominant on these sediments are planosol and luvisol.

3. Large areas of diluvial-proluvial sediments are distinguished in the north part of the Zagreb urban area, as far as to Sesvete. The narrow elongated formations lie at the foot of morphological elevations near Dugo Selo and Štakorovec, the largest area being located in the Zelina depression between Šašinovec and the Nespeš stream valley. The marshy-moor sediments are a typical unit in the south part of the complex. They extend to the east from Zagreb as far as to Vrbovec, south from the magistral road Zagreb - Bjelovar, to the south to Ivanić and in the narrow tarrace segment of the Sava alluvium between Zagreb and Oborovo. Here, the question is about gleyed loess which, unlike the terrestrial one, nearly always is calcareous. In the flood planes of Črnec, Lonja and Zelina, this loess is overlaid by sediments of recent marshlands (most of them reclaimed now), which are thin (< 1 m) and present the markedly humizated clay silts (Basch 1982).

4. Sediments of recent streams are laid perpendicularly to the sloping grounds of Medvednica east and south-east slopes in the flood plane of Vrbovec's Črnec, Dulepska and the Lonja River upper stream. They are of a very heterogeneous lithological structure.

The Sava Flood Valley
Naplavna savska dolina

The Sava flood valley is characterized by gravel-sand and loam-clay deposits overlaying the old lacustrine sediments.

1. The alluvium of recent streams is limited now to small river islands, beaches and sand-shelfs of the Sava River and to a lesser degree of the Krapina River.

2. The alluvium of the Sava first and second terraces is, in some localities, more than 100 m thick. Its average thickness is between 30 and 40 m; in the longitudinal profile it increases in the west-east direction while in the cross-section it decreases when approaching the Sava valley edges.

The second Sava terrace is developed with minor interruptions throughout the Sava stream, from the border with Slovenia to Oborovo. It consists of alteration of coarse-grained gravels and sands. The amount of sand in relation to gravel increases in the south-east direction, and petrographic structure is very varied. Most often there occur well rounded and elongated pebbles of carbonate rocks, then of chert, quartzite, sandstone and eruptive rocks.

The first Sava terrace is developed fragmentarily along the Sava stream, from the Slovenian border to Jakuševec. It is less wide than the previous one and on it dominant is the coarse-grained gravel. The layers of pure sand are thinner and less frequent, but mineral composition is the same as in the second terrace.

3. The flood sediments (the inundation area facies), as a thin cover of fine-grained material, lie over almost the entire Sava River valley. These are mainly sand-clay silts with transition into silty clays.

Samoborsko gorje and Žumberak
Samoborsko gorje i Žumberak

This south-west area of the City and the County is characterized chiefly by calcareous sediments. These are dolomites, subordinately limestones, marls, shales, cherts and tuffs of Triassic age. The Upper Triassic dolomites are the most important lithological elements and soil parent material in the east Žumberak pedosphere. They extend from the Sava and Krka Rivers in the north to Plešivica - Slavetić - Rude stretch in the south. In the north-east Žumberak as well as in the central part of Samoborsko gorje there are also deposits of Jurassic limestones, calcareous breccias, siliphicated limestones, cherts and dolomites.

In addition to these sediments, in a somewhat larger area there are also, mosaically spread, the Upper Cretaceous breccias, conglomerates, shales, marls, calcareous clastites and cherts.

Plešivica piedmont region and Vukomeričke gorice with the Kupčina basin
Plešivičko prigorje i Vukomeričke gorice sa središnjim brežuljkastim područjem i dolinom Kupčine

In its western part, in the region of Plešivica and Samoborsko gorje, this complex is a continuation of marls, sands, sandstones, conglomerates and breccias.

This is a unique zone from Sv. Nedjelja through Sv.Jana to Novakovića gorice. Thus, the region of Samobor presents a lithological enclave with proluvial gravels, sands and clays in its piedmont part, and terrestrial carbonate-free loess in the valley near the Sava River. These Aeolic deposits of terrestrial loess continue from Sv.Nedjelja and Marija Gorica hills through the continuous zone of Turopolje to the south-east, between Vukomeričke gorice and the Sava valley. Their main characteristic is a very small percentage of calcium carbonate, and they are known also by the name of "clayed loess", "carbonate-free loess" and "marbled loams" (Pikija 1987).

In the east part of this zone, near Buševec, between Vukomeričke gorice and the Sava valley, there are the deluvial-proluvial silts, sands and gravels, while mosaically between Rakov Potok and Hudi Bitek as well as near G. Lukovac, the moor loess deposits occur, too (Šikić et al. 1978).

The south part of the City and the County is represented, in terms of lithology, by the Plio-Pleistocene sediments - gravels, sands, clays and sporadically sandstones and conglomerates. This is the region from Rakov Potok to the south and south-west, as well as to the south-east through Vukomeričke gorice as far as to Pokupsko. The fine-grained sediments are determined as sands, silty sands, clay sands, silts, clay silts and silty or sandy clays.

Table 1. Typical lithosequence in the Zagreb County forest pedosphere
Tablica 1. Karakteristične litosekvence u pedosferi šuma Zagrebačke županije

Nr. *Br.*	Rocks *Stijene*	Soil *Tlo*
1	Quartz-sericite-schists, green schist *Kvarc-sericitni škriljac, zeleni škriljac*	Distric leptosol - Distric cambisol *Ranker - distrični kambisol*
2	Quartz-calcite-sericite schists, calcite phyllites *Kvarc-kalcit-sericitni škriljac, kalcitni filiti*	Rendzic leptosol - Eutric cambisol *Rendzina - eutrični kambisol*
3	Clays, loams *Gline, ilovine*	Planosol *Pseudoglej*
4	Sacharoide dolomite *Saharoidni dolomiti*	Rendzic leptosol *Rendzina*

The southern part of this complex, toward the Kupčina and Crna Mlaka basin, is built mostly of the Holocene clay deposits with interbeds and lens of sands, clay sands and clay gravels.

From the point view of soil genesis, the most important characteristics of rocks are chemical composition and wear properties. In this respect we can talk about rocks with different status of nutrients, the rocks with various physical and chemical properties of wear, and finally the lithosequence of soils (Tab. 1).

CLIMATE
KLIMA

Climatically, the Zagreb County is a transitory region where, in addition to the influence of general circulation characteristical for these latitudes, a strong modifying influence of the Pannonian plane and the large mountain ranges of Alps and Dinaric Alps is felt either, that compensates to a certain degree the Atlantic and especially the Mediterranean influences.

In terms of the general climatic characterization, the Zagreb County according to the Thorntwait's classification has humid climate, and according to the Köppen's classification moderately warm rainy climate of Cfwbx" type. Over the year there is no dry season, and precipitations are distributed in a regular manner. These climatic features exclude the frosty and exudative type of soil water regime. The extreme climatic characteristics in the sense of climate perhumidity are typical for the highest parts of Medvednica and Žumberak only. With regard to the recognizable influence of recent climate to the pedogenesis, it can be said that in this relatively small region there are no climate-sequence soils, namely the series of soils whose pedosystematic belonging and physiographic characteristics are attributable to the climatic influence only.

On some soils of this region, according to their physiographic properties and the general characteristics of pedosphere, the Paleoclimatic influences are noticeable, which are attributable to the Pleistocene period. These are as dominant in one case the typical endomorphological symptoms of the so-called tundra soils, which are present in the largest number of silty and silty clay soils on loams and clays.

ORGANISMS
ZOOCENOZA

Organisms, as a group of pedogenetic factors, play an important role in the soil genesis, in particular by the production of organic matter, the organic and mineral substance transformation processes and the migration processes. The most evident determinant of organisms as the factor of soil genesis is vegetation. The question is of course, about the soils under one and only type of vegetation, the forest vegetation, so in this sense we can talk about the influence of particular forest species or associations on the properties of the soil and its evolution. This being outside the framework of the general description of soils, it is enough to say that the forest vegetation structure is made of a wide spectrum of associations, from the willows and poplars of the Sava alluvial terrace to the beech forests and the beech and fir forests in the upper parts of Medvednica and Žumberak, and that there are no distinctly marked phytosequences.

RELIEF
RELJEF

By redistribution of substances and energy on the soil surface, the relief plays an important role in the soil development and in the formation of physiographic properties of particular soils.The most direct influence of relief on soil properties, by means of the redistribution of substances on the soil surface and by lateral movement of water through the soil profile, is seen in the conditions of pronounced inclinations of the ground. Physical wearability of parent material and excessive anthropogenetic impacts in such circumstances are factors which facilitate gradual impoverishment of the upper, higher parts of the ground in organic matter, the decrease of profile depth and a general change of soil physical properties, in both the deflation zones and the accumulation zones. In the conditions with carbonate parent material, such as flysch and marl, the shallow soil and high pH-value in the upper parts of the slope, as well as the higher depth and power of humus-accumulating horizon in the slope lower parts are particularly visible.

The influence of relief on the distribution of soil types can be shown by the toposequence type series on the mountains and hills as well as by the hydrotoposequence type complexes in flatland parts of the County.

The influence of relief on the general pedogenetic processes is manifested most by the *migration* of soil solid particles and solution. The term used most often to designate carrying of soil particles over the surface and their accumulation in less turbulent parts of relief or water basins is *erosion.*

Under conditions of steeper slopes, being exposed also has an important influence on organic matter transformation processes and this by the correction of hydrothermal regime and microbiological activity. This affects humification, mineralization of organic matter etc.

In the flatland parts of the County, by regulating water table in relation to the soil profile (and surface) and by distributing the flood and stagnant water over the soil surface, the microrelief forms determine the intensity and dynamics of oxidoreduction processes in the soil, namely various types of hydrogenization.

The analysis of pedogenetic factors of forest soils in the Zagreb County indicates a great variability in the structure of soil cover as well as in the soil properties and evolution trends. A specific character to this variability is provided by parent material and relief, so a clear distinction is possible between:

- soils on silicates and metamorphites of Medvednica
- soils on limestones and dolomites of Žumberak and Medvednica
- soils on cohesive carbonate clastites
- soils on alluvial clastites
- soils on Aeolian sediments
- soils on pleistocene loams and clays,

and on the other side:

- soils of inundation areas

- soils of terrace planes
- soils of fluvial-marshy planes (Crna Mlaka depression)
- soils of loess plateaux
- soils of hills (Vukomeričke gorice, Marija Gorica hills)
- soils of premountain steps
- soils of mountain ranges (Medvednica and Žumberak with Samoborsko gorje).

PHYSIOGRAPHICAL PROPERTIES OF SOILS
FIZIOGRAFSKA SVOJSTVA TALA

The properties of soils for such pedogenetically heterogenous region can be illustrated on the most frequent soils and soil groups. The question being about forest ecosystems, the largest weight is given to the most important soil properties for the growth and development of forest vegetation.

RENDZIC-LITHIC LEPTOSOL
VAPNENAČKO-DOLOMITNA CRNICA

The rendzic-lithic leptosol is insignificantly represented soil, and this on the highest peaks of Žumberak only. The soil is developed over pure limestones, it is shallow, very humose and of neutral to weakly acid reaction. It is mostly in the form of cambic rendzic-lithic leptosol. These soils are of a very low production potential, occurring as inclusions with calci-mollic cambisols and luvisols.

RENDZIC LEPTOSOL
RENDZINA

The rendzic leptosol has a very large share in the forest ecosystems of the Zagreb County. The most frequent are three subtypes:

- rendzic leptosol on dolomite
- rendzic leptosol on marl and marly limestones
- rendzic leptosol on Miocene limestones.

Rendzic leptosol on dolomite is almost always the low production potential soil, and stands with such soil are characterized by dry and shallow rhizosphere. This rendzic leptosol subtype is represented most in the cartographic units 4 and 6, in the region of Žumberak and Samoborsko gorje, on the south and south-east slopes of Medvednica as well as in its north-east part. The dominant influence on the pedogenesis and properties of this soil has parent material - the physically very wearable dolomite. The soil evolution on such material being very slow, rendzic leptosols are the dominant type of soil on it. These soils are normally shallow, no matter whether calcareous, decarbonated or cambic. In the cambic varieties the depth is somewhat higher (more than 30 cm on the average). They are characterized by meagerness on the plant available phosphorus (Tab. 2). On these soils generally

Table. 2. Mean parameter values of physiographic properties of the A-horizon of some frequent soils
Tablica 2. Srednje vrijednosti parametara fiziografskih svojstava A- horizonta nekih zastupljenijih tala

Soil *Tlo*	Parent material *Matični supstrat*	Plant community *Biljna zajednica*	n	Depth of A- horizon *Deblj. A- horiz.*	Texture *Mehan. sastav - sadržaj čestica (%)* Gravel sand; *Krupni pijesak* (KP) Fine sand; *Sitni pijesak* (SP) Silt; *Prah* (P) Glina; *Clay* (G)				pH		Humus *Humus*	Total nitrogen *Ukupni dušik*	Mob. Phosph *Mob. fosf.*	Mob. Potass. *Mob. kalij*	Karbonates *Karbonati* ($CaCO_3$)
					(KP)	(SP)	P	G	H_2O	1M KCl			P_2O_5	K_2O	
				(cm)	%						g kg-1		mg kg-1		g kg-1
Rendzic leptosol *Rendzina*	Limestones *Mekani vapnenci*	*Epimedio-Carpinetum betuli* /Ht. 1938/ Borh. 1963	4	20.0	9.4	31.8	31.0	27.8	7.9	6.9	177.8	9.40	90.7	234.8	97.5
	Dolomite *Dolomit*	*Lamio orvale-Fagetum sylvaticae* Ht. 1938	3	17.0	3.9	23.3	45.0	27.8	7.5	6.4	86.0	2.77	8.5	140.0	86.3
Calci-mollic cambisol *Smeđe tlo na vapnencu*	Limestone *Vapnenac*		3	16.0	5.5	28.8	38.1	27.6	5.4	4.3	107.7	3.20	26.0	142.5	0.0
Eutric cambisol *Eutrično smeđe tlo*	Marl *Lapor*		5	7.5	3.8	34.0	34.3	27.9	6.1	5.1	88.6	4.12	39.0	274.8	0.0
Dystric cambisol *Distrično smeđe tlo*	Schist *Škriljci*	*Luzulo-Fagetum sylvaticae* Ht. 1938	13	12.0	15.8	34.1	31.0	19.1	4.8	3.9	111.5	4.17	73.0	178.9	0.0
	Schist *Škriljci*	*Querco-Castaneetum sativae* Ht. 1938	4	5.0	30.6	17.3	29.9	22.3	4.6	3.9	216.0	5.90	112.5	208.8	0.0
Luvisol *Lesivirano tlo*	Loess *Prapor*	*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969	5	6.0	3.0	47.8	31.6	17.6	5.2	3.9	53.6	2.34	66.2	134.2	0.0
Planosol *Pseudoglej*	Pleistocene loams *Pleistocenske ilovine*	*Epimedio-Carpinetum betuli* /Ht. 1938/ Borh. 1963	9	16.0	4.3	35.9	40.7	19.2	4.8	3.7	37.6	1.41	5.3	98.2	0.0
		Genisto elatae-Quercetum roboris Ht. 1938	9	9.0	1.6	38.8	41.2	18.4	4.8	3.9	59.3	2.83	18.9	139.8	0.0
Gleyic planosol *Pseudoglej-glejno tlo*			3	12.0	1.3	20.9	43.8	33.9	5.2	4.0	64.7	3.33	121.0	148.3	7.0
Gleysol *Močvarno glejno tlo*		*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969	3	12.0	0.9	47.7	31.7	19.6	4.7	4.0	49.7	2.83	93.0	134.7	0.0
Fluvisol *Aluvijalno tlo*	Alluvium *Aluvij*	*Salici-Populetum nigrae* Rauš 1973	3	13.0	2.1	48.9	36.5	12.6	7.6	7.0	68.0	1.75	35.7	109.0	219.1

the beech forests of poor standing grow, most of which of a limited economic importance. On the south-east slopes of Medvednica and on Žumberak, the sessile oak and hornbeam forests are developed on such rendzic leptosols, too.

Rendzic leptosol on marl and marly limestone is found on Žumberak, in the north-east parts of Medvednica and on Marija Gorica hills. These are mostly deeper soils with a higher production potential than that of the rendzic leptosols on dolomite. Symptomatic for these soils is that their depth corresponds relatively well with the inclination of slopes (Kovačević et al. 1972). Thus, on steep slopes these rendzic leptosols are calcareous to the very surface, while on slight slopes they are debasificated, cambic and in alteration with eutric cambisols and luvisols. By texture, they are predominantly clay loams, of moderate to poor permeability and on slopes very susceptible to erosion. On these soils, on Žumberak and Medvednica, the beech forests and the sessile oak-hornbeam forests are represented about equally, while on Marija Gorica hills the sessile oak - hornbeam forests of medium standing grow.

Rendzic leptosol on the Miocene limestones occupies relatively small areas in the area of calcareolus parent material. In relation to the rendzic leptosols on dolomite and marl, this rendzic leptosol subtype has the most favorable physiographic properties for forest vegetation growing.These soils are with a relatively deep A-horizon (Tab. 2), of loamy texture. On them, on Medvednica, the sessile oak and hornbeam forest grows, less frequently the beech forest, while on Plešivica and Marija Gorica hills the sessile oak and common hornbeam forest is developed.

In addition to the said rendzic leptosol subtypes, it is interesting also a mosaic-like occurrence of rendzic leptosols on calcitic phyllites on Medvednica (Vranković 1973), where they occur in combination with dystric cambisols and dystric leptosols.

DYSTRIC LEPTOSOL
RANKER DISTRIČNI

The dystric leptosol occurs on phyllites and schists on Medvednica. This soil is limited to steeper slopes, where it represents a permanent stage due to erosion and colluvial processes. It is usually in association with the dystric cambisol which is the main constituent in such association. This is a shallow to moderately deep and skeletal soil, with the lowest production potential of all other soils on the rocks of green schist facies. It is of acid reaction, loamy texture, very humose, and the limiting factor of its fertility is shallowness.

CALCI-MOLLIC CAMBISOL
SMEĐE TLO NA VAPNENCU

This soil occurs on pure limestones in the central and southern parts of Žumberak as well as in the north-east part of Medvednica. It is in association with rendzic-lithic leptosols and luvisols, as well as rendzic leptosols. With rendzic leptosols it usually occurs in a mosaic-like form on dolomite which physically do not wear so much, so in the profile there is a very thin layer of worn away carbonate on its bottom. The moderately deep and deep varieties of these soils are of high production potential, with loamy to clay-loamy texture, and on them the high quality beech stands are developed. The lowest quality is in the soils in association with rendzic leptosols, and shallow varieties in general.

DYSTRIC CAMBISOL
DISTRIČNO SMEĐE TLO

The genesis of this soil is connected with the quartz-silicate metamorphites and sediments of Medvednica, Žumberak (the parts of Plešivica and Samoborsko gorje) and Marija Gorica hills. These are soils of A-(B)-C profiles, of acid to high acid reaction (Tab.2), loamy to sandy loamy texture, and their depth depends on the kind of parent material (slates, schists, phyllites, sandstones, conglomerates, cherts, sands), the direction of schistosity in schists and phyllites and the inclination of slopes. Their production potential depends on the depth and the trophic level. The low fertility variants are sandy, shallow, possibly skeletal, very acid and with a poor cation exchange capacity (CEC). On these soils, the beech and fir associations, the mountain beech forests, the sessile oak and sweet chesnut forests and the sessile oak forests grow.

EUTRIC CAMBISOL
EUTRIČNO SMEĐE TLO

This soil is developed on marls, Miocene limestones, loess and carbonate alluvium. The largest areas of the eutric cambisol on marl and Miocene limestons are on Žumberak, while other variants occur in rare inclusions with other soils, so stagnic and gleyized variants are found, too. The eutric cambisol on marl and limestone has a high production potential. These soils are moderately deep to deep, of loamy clay texture, of low acidity and with the high base cationic exchange capacity. On these soils, the mountain beech forests and the sessile oak and common hornbeam forests grow.

LUVISOL
LESIVIRANO TLO

This soil is very frequent in the County forest ecosystems. It occurs in different variants and forms on both the carbonate and the silicate and silicate-carbonate parent material, except on sandstones, alluvial sediments and diluvial clays. The most frequent varieties are those on loess and loams of Vukomeričke gorice, while somewhat less frequent are varieties in the Plešivica boundary area and to the north from Vrbovec. These soils are deep to very deep, and of very high production potential. On the luvisols of Vukomeričke gorice and Plešivica the sessile oak and common hornbeam association and the beech forests are developed, while in levelled positions, on the pseudogleyized or gleyized varieties, the common oak and common hornbeam forests grow. On Medvednica, the luvisols on metamorphites are very rare, usually in lower, levelled positions. On Žumberak, they are a bit more frequent and occur on limestones and marls in the mountain beech forests and the sessile oak and hornbeam forests. On such parent material, these are the soils with the best physiographic properties and of the highest production potential. For this reason, in the past many of them were made suitable for farming by forest clearing, especially those in level positions.

REGOSOL
KOLUVIJALNO TLO

Regosol is soil occurring usually in stream and torrent gullies of Medvednica, Žumberak and Samoborsko gorje, especially on levelled parts of steep slopes. The physigraphic properties of these soils do not depend on the properties of parent material but on the material displaced from higher positions in relief. This fact explains the great diversity in physiographic properties of these soils. Nevertheless, it can be said that, in the cartographic units in which these soils are found, the most often they are of the highest production potential. In rare cases, however, as a limiting factor a high skeletal character or prevailing reduction conditions inside the profile occur.

PLANOSOL
PSEUDOGLEJ

The planosol is the most represented type of soil in the forest ecosystem pedoshpere of the County. Especially spread is the slope subtype on diluvial loams and clays. Dominant on this soil is the sessile oak and hornbeam forest, and to a lesser extent the mountain beech forest. These are acid to very acid soils of loamy texture, with very bad drainage characteristics and unfavorable proportions of capillary and non-capillary pores. Nevertheless, in the natural forest ecosystems of the County, these are the soils of a high production potential. In relation to the planosol on loams, the planosol on marl and loess is an eutric variant with favorable physiographic properties (pH value in water above 5,5, the high CEC value).

The flatland planosol is characterized by a slight lateral flow inside the profile, with the wet phase longer than that in the slope subtype. On this soil, the most frequent association is that of sessile oak and hornbeam as well as the association of common oak and large greenweed. Of all forest soils, the planosol has the smallest humus reserve per unit of surface.

GLEYSOL
MOČVARNO GLEJNO TLO

This soil is hydrologically conditioned either by the high ground water table (inside the profile or even above the surface) or by an extremely bad natural drainage of relief depressions. This results in the occurrence of reduction processes in a part of profile or in the whole profile.

Depending on the origin of excess water and the character of hydrogenization, the various subtypes of gleysol occur. Particularly unfavorable, physiologically, are amphygleyic gleysol vertic varieties. The correction factor of physiographic properties of these soils is their water regime. This is at the same time also the limiting factor of production potential when the prevailing reduction conditions inside the profile are concerned.

Gleysol is the most represented on the alluvial sediments of the Sava flood plane. This includes the north-east parts of Odransko polje (Turopoljski lug) and Lonsko polje (the Žurica forest). A larger forest surface with gleysols is also the forest complex Varoški lug, between Vrbovec and Ivanićgrad, as well as the parts of the Kupa basin. The most frequent plant associations on these soils are the common oak forest with greenweed and the common oak and common hornbeam forest. On the vertic amphygleyic gleysol, the common ash forest with late snowflake often occurs, while on the organogenic vertic amphygleyic gleysols the black alder forest with berry alnus is often developed, too.

According to Mayer (1996), in the last decades in the soils of basin ecosystems unfavorable hydrological changes took place, especially in respect to the old stands. These changes are consequences of various infrastructural works (channels, roads, etc.), resulting most often in the lower water table and the physiological drought in the rhizosphere, or in a long lasting surface water stagnation. Particularly alarming is phenomenon of tree withering in Žutica and Turopoljski and Varoški lug. Due to such extremely strong anthropogenic impacts on the soil, the Žutica forest is the most endangered forest complex in the County. The research of redox potential (Vranković and Bašić 1989) showed that in some marshy parts of this forest unfavorable reduction conditions last throughout the vegetation season.

Under conditions of a stable, undisturbed, water regime the hypogleyic gleysol subtype, in particular in the loamy to loamy-clay variant, is the soil of high production potential. On such soils our most valuable common oak and hornbeam forests and the common oak forests with greenweed grow.

In association with the gleysol, especially the hypogleyic gleysol subtype, the texturally heavy soils, which in the upper part of profile have characteristics of planosol and in the lower part those of gleysol, are found sporadically. These are the planosol-gleyic soils, usually with vertic features.

All these soils generally are non- calcareous.

FLUVISOL
ALUVIJALNO TLO

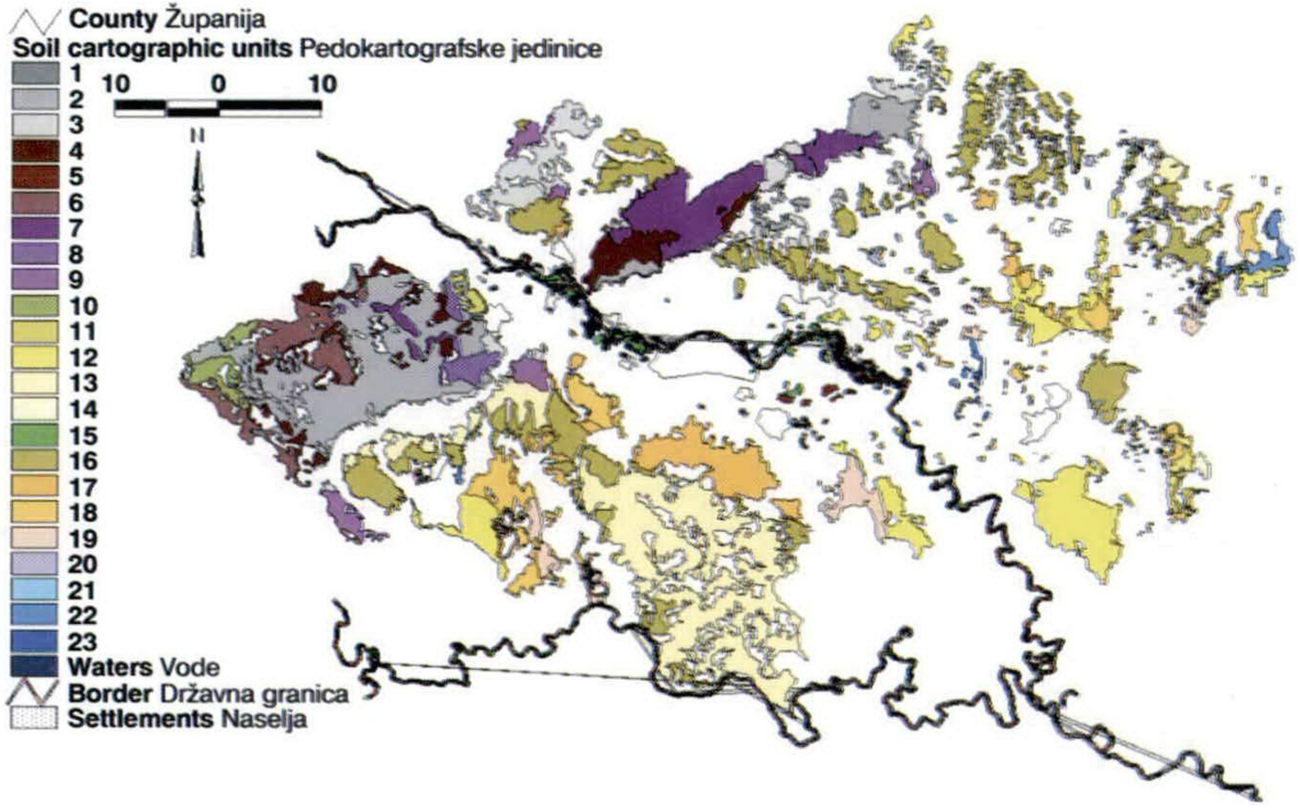
Owing to hydrotechnical works and regulation of most flatland rivers, there is no regular flooding and alluvial sediment accumulation in the flood region. The relatively small surfaces under forests, that remained in the region regularly flooded by the Sava River, are represented by the willow and poplar forests. They grow on the soils formed by periodical sedimentation of alluvial sediment under the influence of carrying power of water. In the profile, these soils show the bedding without any clear morphological signs of genetic horizons. In terms of the texture, these are mainly sand to gravel-sand alluviums with carbonate particles of silty soil. As the question is about relatively small surfaces along the Sava River, these soils have no economic significance. Their production potential is relatively low, that is due to their gravel-sand texture and, consequently, to an extremely unfavorable proportion of capillary and non-capillary pores and insignificant sorption capacity.

GEOGRAPHICAL CHARACTERISTICS OF SOILS
GEOGRAFSKE ZNAČAJKE TALA

The presentation of spatial relations in the forest ecosystem pedosphere of the Zagreb County is based on the attached cartogram (Fig. 1) and the structure of mapping units (Tab.3). The soils of the whole of County forest area are shown by means of 23 complex mapping units (Tab. 3), whose complexity is in compliance with the map scale. The specificity of distribution in space of forest soils and pedocartographic units in the County region has been determined by the above mentioned pedogenetic factors. In this respect, very important is the anthropogenetic factor by which the spatial dimension of forest cover is defined directly. On the attached cartogram, 5 cartographic units comprising the largest forest complexes are clearly distinguished. These are:

1. mapping unit 2 with the soils on carbonate parent material of Žumberak and Medvednica;
2. mapping unit 13 with luvisols and planosols of Vukomeričke gorice;
3. mapping unit 16 with prevailing planosols of piedomont region and hills;
4. mapping unit 23 with gleysols of the Kupa basin, Turopoljski lug, Varoški lug and Lonjsko polje;
5. mapping unit 7 with dystric cambisols on the metamorphites of Medvednica.

These 5 mapping units cover more than 63% of the County forests and are bearers of basic characteristics of the complete forest ecosystem pedosphere.


County Županija
Soil cartographic units Pedokartografske jedinice
1
2
3
4
5
6
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8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Waters Vode
Border Državna granica
Settlements Naselja
10
0
10
N

Table 3. Mapping units of the forest pedosphere of the Zagreb County
Tablica 3. Pedokartografske jedinice šumskih ekosustava Zagrebačke županije

Nr. *Br.*	Dominant unit of soil *Dominantna jedinica tla*	Other units of soil *Ostale jedinice tla*	Inclusions *Inkluzije*	Površina *Area* (ha)	Zastupljenost *Participation* (%)
	2	3	4	5	6
1	Calci-mollic leptosol *Vapnenačko dolomitna crnica*	Calci-mollic cambisol *Smede tlo na vapnencu i dolomitu*	Luvisol; Rendzic leptosol *Lesivirano tlo na čistim vapnencima i dolomitima; Rendzina na mekim vapnencima*	74	0.05
2	Rendzic leptosol *Rendzina na dolomitu i dolomitiziranom vapnencu*	Calci-mollic cambisol; LuvisolSmede na dolomitu; *Lesivirano na dolomitu i vapnencu*	Calci-mollic leptosol *Vapnenačko-dolomitna crnica*	21128	13.57
3	Rendzic leptosol *Rendzina na laporu i mekim vapnencima*	Luvisol *Lesivirano tlo na laporu*	Gleysol; Dystric cambisol; Regosol *Močvarno glejno tlo; Distrično smede tlo; Koluvijalno tlo*	9393	6.03
4	Calci-mollic cambisol *Smede tlo na dolomitu*	Rendzic leptosol *Rendzina na dolomitu;*	*Lesivirano tlo na dolomitu, tipični i akrični*	6258	4.02
5	Eutric cambisol *Eutrično smede tlo na aluvijalnom nanosu, tipično, tipično oglejeno i vertično oglejeno*	Eutric cambisol *Eutrično smede tlo na pretaloženom lesu, tipično i tipično oglejeno*	Gleysol *Močvarno glejno tlo*	408	0.26
6	Eutric cambisol *Eutrično smede tlo na laporu i mekom vapnencu*	Rendzic leptosol; Luvisol; Calci-mollic cambisol *Rendzina na lapor; Lesivirano tlo na silikatno-karbonatnim supstratima; Smede tlo na vapnencu i dolomitu*	Regosol *Koluvijalno tlo*	4892	3.14
7	Dystric cambisol *Distrično smede tlo na metamorfitima i klastitima*	Luvisol *Lesivirano tlo na silikatnim supstratima*	Dystric leptosol; Regosol *Ranker; Koluvijalno tlo*	9107	5.85
8	Dystric cambisol *Distrično smede na silikatnim klastitima*	Luvisol *Lesivirano tlo na silikatnim klastitima; Ranker regolitični*	Regosol; Rendzic leptosol *Koluvijalno tlo distrično; Rendzina na laporu i mekim vapnencima*	1815	1.17
9	Dystric cambisol *Distrično smede tlo, tipično i pseudooglejeno na nevezanim klastitima*	Planosol; Luvisol *Pseudoglej obronačni; Lesivirano tlo, tipično, pseudooglejeno i dvoslojno*	Regosol *Koluvijalno tlo*	3210	2.06
10	Luvisol *Lesivirano tlo na čistim vapnencima i dolomitima, tipično*	Calci-mollic cambisol *Smede tlo na vapnencu u dolomitu, lilimerizirano;*	Calci-mollic leptosol *Vapnenačko-dolomitna crnica*	1698	1.09
11	Luvisol *Lesivirano tlo na čistim vapnencima i dolomitima, tipično i akrično*	Luvisol *Lesivirano i distrično smede tlo na škriljcima i pješčenjacima*	Calci-mollic cambisol *Smede tlo na vapnencima i dolomitima*	533	0.34
12	Luvisol *Lesivirano tlo na laporu i pleistocenskim ilovinama*	Planosol; Rendzic leptosol *Pseudoglej obronačni; Rendzina na laporu, karbonatna*	Leptosol *Koluvijalno tlo s dominacijom sitnice*	1304	0.84
13	Luvisol *Lesivirano tlo na lesu, ilovinama i pjeskovitim ilovačama, pseudooglejeno*	Luvisol; Planosol *Lesivirano tlo na lesu, tipično; Pseudoglej obronačni*	Regosol; Gleysol; Dystric cambisol *Koluvijalno tlo; Močvarno glejno tlo; Distrično smede tlo na lesu;*	25489	16.37
14	Luvisol *Lesivirano tlo na praporu*	Planosol *Pseudoglej obronačni*	Regosol; Gleysol *Koluvijalno tlo; Močvarno glejno tlo*	802	0.51
15	Fluvisol *Aluvijalno tlo, karbonatno*	Fluvisol; Gleysol *Aluvijalno livadno tlo, karbonatno; Močvarno glejno tlo*		1454	0.93
16	Planosol *Pseudoglej obronačni*	Planosol; Luvisol; Dystric cambisol *Pseudoglej ravničarski; Lesivirano tlo na lesu; Distrično smede tlo*	Gleysool; Regosol, Rendzic leptosol *Močvarno glejno tlo; Koluvijalno tlo, aluvijalno-koluvijalno; Rendzina*	27719	17.80

Nr. *Br.*	Dominant unit of soil *Dominantna jedinica tla*	Other units of soil *Ostale jedinice tla*	Inclusions *Inkluzije*	Površina *Area* (ha)	Zastupljenost *Participation* (%)
	2	3	4	5	6
17	Planosol *Pseudoglej ravničarski*	Planosol; Luvisol; Regosol *Pseudoglej obronačni; Lesivirano tlo na lesu, pseudooglejeno; Koluvijalno tlo, aluvijalno-koluvijalno*	Gleysool *Močvarno glejno tlo*	8688	5.58
18	Planosol *Pseudoglej ravničarski*	Planosol; Luvisol; Gleysol *Pseudoglej-glejno tlo; Lesivirano tlo na lesu, tipično i pseudooglejeno; Močvarno glejno tlo*	Eutric cambisol; Regosol *Eutrično smede tlo, pseudooglejeno; Koluvijalno tlo, aluvijalno-koluvijalno*	8836	5.67
19	Gleyic planosol *Pseudoglej-glejno tlo*	Planosol; Luvisol *Pseudoglej ravničarski; Močvarno glejno tlo*	Fluvisol *Aluvijalno livadno tlo*	3671	2.36
20	Gleysol *Močvarno glejno tlo*	Gleyic regosol *Koluvijalno tlo, aluvijalno koluvijalno, oglejeno*	Planosol; Gleyic planosol *Pseudoglej ravničarski; Pseudoglej-glej*	1054	0.68
21	Gleysol *Močvarno glejno tlo*	Humic fluvisol *Aluvijalno livadno tlo*	Fluvisol *Aluvijalno tlo*	45	0.03
22	Gleysol *Močvarno glejno tlo, hipoglejno*	Gleyic planosol *Pseudoglej-glejno tlo; Pseudoglej na zaravni*	Gleysol *Močvarno glejno tlo amfiglejno*	1873	1.20
23	Gleysol *Močvarno glejno tlo, amfiglejno, većinom nekarbonatno*	Gleysol *Močvarno glejno tlo, hipoglejno, većinom nekarbonatno*	Fluvisol; Gleysol; Gleyic planosol *Aluvijalno tlo; Pseudoglej-glej; Močvarno glejno tlo, tresetno*	16276	10.45

CONCLUSIONS
ZAKLJUČCI

In the constelation of the pedogenetic factors, the characteristics of forest ecosystem pedosphere in the Zagreb County are based on the physiographic properties of the following soils:

1. rendzic leptosol
2. dystric cambisol
3. calci-mollic cambisol
4. luvisol
5. planosol
6. gleysol.

The soils with the highest production potential in the County forest ecosystems are luvisols. On various subtypes of this soil, three very important associations are found, namely the mountain beech forest, the sessile oak and hornbeam forest and the common oak and hornbream forest. Particularly favorable physiographic properties are those in the loess overlaid luvisols.

The soils with a limited production potential are various shallow soils, such as rendzic leptosols on dolomite of Žumberak, Samoborsko gorje and Medvednica, and dystric leptosols on schists of Medvednica. These soils, and consequently the forests as a whole, are of a reduced multifunctionality.

In the spatial division of forest pedosphere of the County, 5 cartographic units comprising the largest forest complexes are distinguished in particular. These are:

1. cartographic unit (2) with the soils on carbonate substrata of Žumberak and Medvednica
2. cartographic unit (13) with luvisols and planosols of Vukomeričke gorice
3. cartographic unit (16) with prevailing planosols of piedmont regions and hills
4. cartographic unit (23) with gleysols of the Kupa basin, Turopoljski lug, Varoški lug and Lonjsko polje
5. cartographic unit (7) with dystric cambisols on metamorphites of Medvednica.

These 5 cartographic units cover more than 63% of the County forests and are bearers of basic characteristics of the complete forest ecosystem pedosphere.

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TLA ŠUMSKIH EKOSUSTAVA ZAGREBAČKE ŽUPANIJE

SAŽETAK

Zagrebačka županija nalazi se u zapadnom dijelu središnje Hrvatske. Zajedno s Gradom Zagrebom prostire se na 3 720 km^2, što je oko 6,6 % teritorija Republike Hrvatske. Površina šuma i šumskih zemljišta je 1 560 km^2, što je oko 42 % površine Županije.

Pedogenetske značajke pedosfere šumskih ekosustava ove Županije najjače su obilježena matičnim supstratom.

Područje Grada Zagreba i Zagrebačke županije u litološkom smislu vrlo je složene i izrazito heterogene građe.

Na tom je području moguće izdvojiti 5 geomorfološko-litoloških kompleksa s nizom litoloških jedinica.

I. Medvednica
II. Ravnično i brežuljkasto područje lijevoga savskoga zaobalja
III. Naplavna savska dolina
IV. Samoborsko gorje i Žumberak
V. Plešivičko prigorje i Vukomeričke gorice sa središnjim brežuljkastim područjem i dolinom Kupčine.

Glavne su skupine matičnih supstrata:

1. metamorfiti Medvednice
2. vapnenci i dolomiti Žumberka, Samoborskoga gorja i Medvednice
3. lapori i meki vapnenci Žumberka s Plešivicom i Samoborskim gorjem, Medvednice i marijogoričkih brda
4. pleistocenske ilovine i gline te prapor Vukomeričkih gorica, marijogoričkih brda, pobrđa istočnoga dijela Županije te medvedničkoga i žumberačkoga prigorja
5. kvartarni talozi Posavine i Pokuplja.

Vrlo značajni korigirajući pedogenetski čimbenici u danim geološkim i klimatskim prilikama u tom su prostoru reljef i čovjek.

U konstelaciji navedenih čimbenika obilježja pedosfere šumskih ekosustava Zagrebačke županije temelje se na fiziografskim svojstvima ovih tala:

1. rendzina
2. distrično smeđe tlo
3. smeđe tlo na vapnencima i dolomitima
4. lesivirano tlo
5. pseudoglej
6. euglej.

U kombinaciji s tim tlima, kao sporedne jedinice i inkluzije, javljaju se još: koluvijalno tlo, vapnenačko-dolomitna crnica, ranker distrični, eutrično smeđe tlo, fluvisol, humofluvisol, pseudoglej-glej.

Tla s najvećim proizvodnim potencijalom u šumskim ekosustavima Županije su lesivirana tla. Na različitim podtipovima toga tla susreću se tri vrlo značajne zajednice, a to su brdska bukova šuma, šuma hrasta kitnjaka i graba te šuma hrasta lužnjaka i graba. Osobito povoljnih fiziografskih svojstava su lesivirana tla na praporu.

Tla ograničenoga proizvodnoga potencijala su različita plitka tla, kao što su rendzine na dolomitima Žumberka, Samoborske gore i Medvednice, te rankeri na škriljcima Medvednice. Ta su tla, pa tako i šume u cjelini, smanjene multifunkcionalnosti.

S druge strane tla narušene multifunkcionalnosti su tla poplavnih ekosustava, primjerice u Turopolju, Pokuplju i Lonjskom polju. Ta tla nisu promijenila svoja svojstva, ali su se hidrološke prilike uvelike pogoršale, što štetno djeluje osobito na stare šumske sastojine. Te se promjene pripisuju različitim infrastrukturnim zahvatima u prostoru (kanali, ceste itd.), a očituju se najčešće spuštanjem razine podzemne vode i izazivanjem fiziološke suše u zoni rizosfere ili dugotrajnim stagniranjem površinske vode.

U prostornoj raščlambi pedosfere šuma u Županiji izdvaja se osobito 5 kartografskih jedinica koje obuhvaćaju najveće šumske komplekse. To su:

1. kartografska jedinica (2) s tlima na karbonatnim supstratima Žumberka i Medvednice
2. kartografska jedinica (13) s lesiviranim i pseudoglejnim tlima Vukomeričkih gorica
3. kartografska jedinica (16) s pretežito pseudoglejnim tlima prigorja i pobrđa
4. kartografska jedinica (23) s glejnim tlima Pokuplja, Turopoljskoga luga, Varoškoga luga i Lonjskoga polja
5. kartografska jedinica (7) s distričnim smeđim tlima na metamorfitima Medvednice.

Tih 5 kartografskih jedinica pokriva preko 63 % šumskih površina Županije i nositelji su temeljnih obilježja ukupne pedosfere šumskih ekosustava.

Ključne riječi: Zagrebačka županija, tlo, pedosfera

UDK: 630*624

Original scientific paper
Izvorni znanstveni članak

MANAGEMENT OF FOREST RESOURCES IN THE ZAGREB COUNTY

GOSPODARENJE ŠUMSKIM DOBRIMA U ZAGREBAČKOJ ŽUPANIJI

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Zagreb County with the City of Zagreb, encompassing 30,000 km², is a very densely populated and developed area. With regard to such distinct population density, the importance and functions of forests are very large. The paper gives a survey of the current condition of forests and forestland in terms of ownership structure, purpose of forests, structure per tree species, management classes, age structure per area and growing stock, as well as potential productive capacities. The forested area amounts to 139,275 ha, of which 35,027 ha (26%) are mainly privately owned coppice forests. Brushwood covers an area of 1,419 ha, while productive non-covered forestland extends over only 1,757 ha. Commercial forests cover an area of 136,650 ha with 22.31 million m³ of growing stock, which produces 750,000 m³ (6.38 m³/ha) annually. Although forests and forestland cover 1,400 km², which is 46.7% of the total area of the district, management with forest resources should be aimed at increasing potential productive capacities of all resources. With the support of the system dynamic model based on the defined management guidelines, the article discusses the predicted future development of these forests, which can be used as a starting point for rough long-term planning at a regional level. With regard to the trends in the area, growing stock and prescribed yield, simulation results have shown that consistent management could result in significant potential productive capacities of these forests. An increase in the area of high forests by 30,000 ha, an increase in the growing stock by 7.8 mil. m³, an increase in the annual prescribed yield by 215,000 m³, and an increase in silvicultural activities are some of the fundamental postulates of future management.

Key words: forest management, age class distribution, future management guidelines, trends in growing stock and prescribed yield, silvicultural activities, system dynamic modelling

INTRODUCTION
UVOD

Zagreb County, popularly known as the "Zagreb Ring", with a population of about 280,000, extends over about 3,000 km² between the boundary with Slovenia, Moslavina, and the River Kupa and the Bjelovar-Bilogora County. Together with the City of Zagreb of about 600 km² and 1,000,000 inhabitants, it is a very developed and densely populated area.

The total area of forests and forestland in the area is 139,275 ha with a growing stock of 22.31 mil. m³. Although the area under forests of 40% corresponds to the Croatian average, the highly complex and strained nature of the region requires that significant attention be paid to the forest resources of the area. Most forests and forestland occur in the lowland and hilly regions, and a smaller portion covers the belt of higher hills. In the past, when these forests covered much larger area and when they were stable, they were deliberately cleared in order to expand agricultural land and gain space for settlements. At present, over 50% of the families in the area of Zagreb County own agricultural land. Privately owned forests also make up 50% of all the forests and forestland. In the last hundred years, due to unfavourable impacts of harmful insects and fungi, climatic changes and hydro-ameliorative treatments (Mayer 1993), the stability of the lowland forest ecosystem has been disrupted and site conditions changed (Meštrović et al. 1996). With increased urbanisation, there is growing awareness of the need to maintain general sustainability and diversity and preserve the genetic potential of rare plant and animal species. Significant effort should be put not only into preserving and improving the existing forests in their present areas, but also into increasing the areas under forests. The task of foresters is to monitor and study the changing relations in forest ecosystems and predict trends so that management includes all the necessary procedures that are best suited to re-establishing disturbed stability. Extensive research has been carried out into lowland forests (Dekanić 1962, 1975; Klepac 1964, 1971, 1982, 1988; Pranjić 1970; Prpić 1974; Pranjić et al. 1988; Meštrović 1989; Rauš 1992; Matić and Skenderović 1993; Mayer 1993; Prpić et al. 1997), which have undergone significant changes in the past few decades.

The aim of this work is to present the characteristics of forests resources in the area of Zagreb County and the City of Zagreb, their potential productivity, the guidelines of future management and predicted development of the most important economic indicators in the studied forests. This will be done with the help of the system dynamic modelling (Čavlović 1996, 1999).

THE CONDITION OF FOREST RESOURCES
STANJE ŠUMA I ŠUMSKOG ZEMLJIŠTA

An overview of forest resources in Zagreb County has been obtained from the data in the forest management plan of the area. The data were obtained by allotting the data from the management plan to the year in which the regional forest management plan in Croatia came into force. The four forest administrations within the area of Zagreb County include Zagreb with 6 forest offices and 27 management units, Bjelovar with 2 forest offices and 6 management units, Karlovac with 2 forest offices and 9 management units, and Sisak with 2 forest offices and 2 management units over 143,123 ha. The land under forests accounts for 139,275 ha, of which coppice forests cover 35,027 ha (2.6%), mainly within private forests. Brushwood covers 1,419 ha, while productive non-covered forestland accounts for only 1,757 ha.

There are three main forms of forest ownership in the area of Zagreb County. These are state-owned forests managed by "Hrvatske šume", other public forests and private forests.

The structure of the forests in Zagreb County according to ownership is shown in Table 1.

Table 1. The structure of forests according to ownership
Tablica 1. Struktura šuma prema vlasništvu

Owner *Vlasništvo*	Total area *Površina*		Total growing stock *Zaliha*		Annual increment *Prirast*	
	ha	%	m^3	%	m^3	m^3/ha
State - *Državne*	68,306.87	49.04	15,602,971	67.69	435,528	6.38
Private - *Privatne*	69,418.79	49.84	7,179,030	31.14	307,169	4.42
Other public - *Ost.*	1,548.89	1.12	269,259	1.17	7,309	4.72
Total - *Ukupno*	139,274.55	100.00	23,051,260	100.00	750,006	5.39

The proportion of state-owned and privately owned forests per area is equal, however, the growing stock in state-owned forests is twice as large as in the latter. This difference is due mainly to lower forest stocking in private forests, and partly to underestimated growing stock.

According to use, all the forests are categorised by their primary function into commercial, protective and forests of special assignment. Table 2 shows forests in terms of their assignment:

Table 2. The structure of forests according to assignment
Tablica 2. Struktura šuma prema namjeni

Kategory of forest *Kategorija*	Total area *Površina*		Total growing stock *Zaliha*		Annual increment *Prirast*	
	ha	%	m^3	%	m^3	m^3/ha
Comercial - *Gospod.*	136,650	95.48	22,307,643	96.77	750,006	6.38
Special assign. - *Spec.*	2,683	1.87	267,157	1.16	-	-
Protective - *Zaštitne*	3,790	2.65	476,460	2.07	-	-
Total - *Ukupno*	143,123	100.0	23,051,260	100.0	750,006	6.38

It is clear from the table that commercial forests are the best represented, while the forests with special assignment and protective forests are represented with only 4.52% per area.

Due to their high economic, ecological and social importance, commercial forests will be presented in more detail and their potential productive capacity shown.

COMMERCIAL FORESTS - THE EXISTING STATE AND POTENTIAL PRODUCTIVE CAPACITIES

GOSPODARSKE ŠUME – POSTOJEĆE STANJE I POTENCIJALNE PROIZVODNE MOGUĆNOSTI

THE STRUCTURE OF GROWING STOCK AND INCREMENT ACCORDING TO TREE SPECIES
STRUKTURA DRVNE ZALIHE I PRIRASTA PO VRSTAMA DRVEĆA

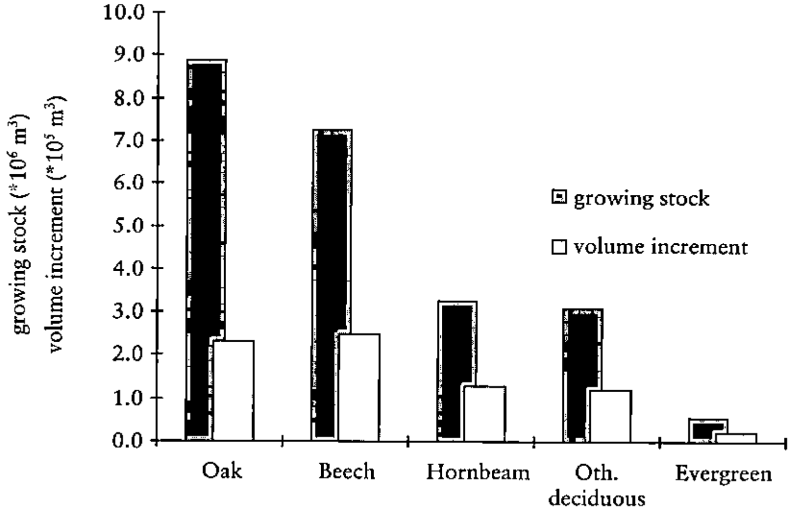
The proportion of growing stock and increment according to tree species is shown in the following table and figure:

Table 3. The structure of growing stock and increment according to main tree species
Tablica 3. Struktura drvne zalihe i prirasta za glavne vrste drveća

Tree species *Vrsta drveća*	Growing stock *Drvna zaliha*		Ann. vol. increment *God. vol. prirast*	
	m^3	%	m^3	%
Pedunc. and sessil. oak - *Hrast*	8,868,388	38.5	232,252	31.0
Beech - *Bukva*	7,256,020	31.5	248,088	33.1
Hornbeam - *Grab*	3,278,141	14.2	126,874	16.9
Other deciduous - *Ost. bjelogorica*	3,075,277	13.3	119,450	15.9
Total deciduous - *Ukupno bjelog.*	22,477,826		726,664	96.9
Evergreen - *Crnogorica*	573,434	2.5	23,342	3.1
Total - *Ukupno*	23,051,260	100.0	750,006	100.0

In terms of the basic division of trees into coniferous and deciduous species, the former are represented with only 2.5% in Zagreb County. The largest growing stock belongs to the most valuable tree species in Croatia, the pedunculate oak and the sessile oak, with 38.5% of the total growing stock. Beech accounts for a significant 31.5%, and the remaining 27.5% are shared equally by hornbeam and other deciduous species. In terms of proportional participation according to growing stock, the increment of beech, hornbeam and other deciduous trees slightly exceeds that of the oak.

Figure 1. The structure of growing stock and increment according to principal tree species
Slika 1. Struktura drvne zalihe i prirasta za glavne vrste drveća



These basic data are an indication of a very favourable structure in terms of tree species in the forests of Zagreb County. This is particularly true for state-owned forests, while poor utilisation of site potential in private forests points to extensive possibilities not only of increasing the growing stock but also of improving the structural relations among the tree species in these forests.

AGE STRUCTURE PER AREA AND GROWING STOCK
DOBNA STRUKTURA PO POVRŠINI I DRVNOJ ZALIHI

Table 4 shows the current age class distribution per area, growing stock and annual increment within 6 management classes. The normal age class distribution has been obtained on the basis of the current state and the related growth yield tables.

Table 4. Current and normal age class structure per area and growing stock for management classes of high forests
Tablica 4. Stvarna i normalna dobna struktura po površini i drvnoj zalihi za uređajne razrede visokih šuma

Management class of Pedunculate oak	AGE CLASSES							Total
	0-20	21-40	41-60	61-80	81-100	101-120	121-140	
	years							
Actual area (ha)	5557	2856	2883	4330	5150	4986	1939	27701
Normal area (ha)	3957	3957	3957	3957	3957	3957	3957	27701
Actual growing (m^3)		334152	570834	1052190	1845245	1635467	754298	6192186
stock (m^3/ha)		117	198	243	358,3	328	389	

Norm. growing (m^3)		629208	1210929	1673932	2014258	2255653	2421859	10205840
stock (m^3/ha)		159	306	423	509	570	612	
Management class of Sessiliflora oak	AGE CLASSES							Total
	0-20	21-40	41-60	61-80	81-100	101-120	121-140	
	years							
Actual area (ha)	1553	2557	4066,5	4027	1805	1245	311	15565
Normal area (ha)	2224	2224	2224	2224	2224	2224	2224	15565
Actual growing (m^3)		294055	792968	914129	608285	399709	113625	3122770
stock (m^3/ha)		115	195	227	337	321	365	
Norm. growing (m^3)		300182	500304	664848	791591	891652	969477	4118054
stock (m^3/ha)		135	225	299	356	401	436	
Management class of Beech	AGE CLASSES							Total
	0-20	21-40	41-60	61-80	81-100	101-120	121-140	
	years							
Actual area (ha)	3706	8143,2	9481,6	8145	4870	3053	763	38162
Normal area (ha)	7632	7632	7632	7632	7632			38162
Actual growing (m^3)		920182	1848912	1800045	1563270	952524	277819	7362751
stock (m^3/ha)		113	195	221	321	312	364	
Norm. growing (m^3)		923520	1808879	2564486	3175078			8471964
stock (m^3/ha)		121	237	336	416			
Management class of Ash	AGE CLASSES							Total
	0-20	21-40	41-60	61-80	81-100	101-120	121-140	
	years							
Actual area (ha)	455,4	576,0	531,3	370,0	369,6	202,4	25,3	2530
Normal area (ha)	633	633	633	633				2530
Actual growing (m^3)		54720	86602	73260	111250	64363	8400	398594
stock (m^3/ha)		95	163	198	301	318	332	
Norm. growing (m^3)		65148	132825	184058				382030
stock (m^3/ha)		103	210	291				
Management class of Hornbeam	AGE CLASSES							Total
	0-20	21-40	41-60	61-80				
	years							
Actual area (ha)	2075	4005	2526	413	91			9110
Normal area (ha)	2278	2278	2278	2278				9110
Actual growing (m^3)		492615	411738	78057	26783			1009193
stock (m^3/ha)		123	163	189	294			

Norm. growing (m^3)		275578	471443	589873				1336893
stock (m^3/ha)		121	207	259				
Management class of Black alder	AGE CLASSES							Total
	0-10	11-20	21-30	31-40	41-50			
	years							
Actual area (ha)	1114	1300	684	432	196	118	78	3922
Normal area (ha)	784	784	784	785	785	0	0	3922
Actual growing (m^3)		118300	99920	79813	50202	34945	23846	407025
stock (m^3/ha)		91	146	185	256	297	304	
Norm. growing (m^3)		48633	120798	163155	192178	0	0	524764
stock (m^3/ha)		62	154	208	245			

Table 5. Actual and normal age structure per area and growing stock for management classes of coppice forests

Tablica 5. Stvarna i normalna dobna struktura po površini i drvnoj zalihi za uređajne razrede niskih šuma

Management class of Pedunculate oak	AGE CLASSES							Total
	0-10	11-20	21-30	31-40				
	years							
Actual area (ha)	23	64	148	57	53	23	11	379
Normal area (ha)	95	95	95	95				379
Actual growing (m^3)		4897	20841	9494	14751	6777	3877	60636
stock (m^3/ha)		76	141	167	278	298	341	
Norm. growing (m^3)		4846	12038	16259				33144
stock (m^3/ha)		51	127	172				
Management class of Sessiliflora oak	AGE CLASSES							Total
	0-10	11-20	21-30	31-40				
	years							
Actual area (ha)	306	1064	2153	987	298	111	50	4969
Normal area (ha)	1242	1242	1242	1242				4969
Actual growing (m^3)		92568	299267	160881	81392	34907	16447	685463
stock (m^3/ha)		87	139	163	273	314	331	
Norm. growing (m^3)		60653	150654	203481				414787
stock (m^3/ha)		49	121	164				
Management class of Beech	AGE CLASSES							Total
	0-10	11-20	21-30	31-40				
	years							
Actual area (ha)	542	3925	4315	2357	786	542	1084	13551

Normal area (ha)	3388	3388	3388	3388				13551
Actual growing (m^3)		337533	582525	381834	211434	163154	366419	2042899
stock (m^3/ha)		86	135	162	269	301	338	
Norm. growing (m^3)		162256	403024	544344				1109624
stock (m^3/ha)		48	119	161				
Management class of Ash	AGE CLASSES							Total
	0-10	11-20	21-30	31-40				
	years							
Actual area (ha)	29	3	12	14	10	1		68
Normal area (ha)	17	17	17	17				68
Actual growing (m^3)		185	1480	2026	2897	398	0	6986
stock (m^3/ha)		68	128	149	284	293	329	
Norm. growing (m^3)		775	1924	2599				5298
stock (m^3/ha)		46	113	153				
Management class of Hornbeam	AGE CLASSES							Total
	0-10	11-20	21-30	31-40				
	years							
Actual area (ha)	2085	3675	3785	1922	782	0	780	13029
Normal area (ha)	3257	3257	3257	3257				13029
Actual growing (m^3)		312375	550718	292205	197780	0	255138	1608216
stock (m^3/ha)		85	146	152	253	356	327	
Norm. growing (m^3)		154491	383737	518294				1056522
stock (m^3/ha)		47	118	159				
Management class of Black alder	AGE CLASSES							Total
	0-10	11-20	21-30	31-40				
	years							
Actual area (ha)	193	347	308	180	116	77	64	1284
Normal area (ha)	321	321	321	321				1284
Actual growing (m^3)		23659	39839	25202	26249	21017	18579	154546
stock (m^3/ha)		68	129	140	227	273	289	
Norm. growing (m^3)		14927	37076	50076				102078
stock (m^3/ha)		47	116	156				

Table 6. Actual and normal age structure per area and growing stock of high and coppice forests in total

Tablica 6. Prikaz stvarne i normalne dobne strukture po površini i volumenu sveukupno za visoke i niske šume

Seed forests	AGE CLASSES							
	I	II	III	IV	V	VI	VII	
Actual area (ha)	14460	19437	20173	17716	12482	9604	3117	96990
Normal area (ha)	17508	17508	17508	17508	14598	6181	6181	96990
Actual growing stock (m^3)		1721409	3399235	3919437	4178251	3087008	1177987	17483327
Norm. growing stock (m^3)		2242269	4245177	5840351	6173106	3147305	3391336	25039544
Copice forests	I	II	III	IV	V	VI	VII	
Actual area (ha)	3177	9078	10721	5517	2045	754	1990	33280
Normal area (ha)	8320	8320	8320	8320	0	0	0	33280
Actual growing stock (m^3)		771217	1494669	871643	534503	226253	660462	4558746
Norm. growing stock (m^3)		397948	988452	1335052	0	0	0	2721452
Total	I	II	III	IV	V	VI	VII	
Actual area (ha)	17637	28515	30893	23233	14527	10359	5107	130270
Normal area (ha)	25828	25828	25828	25828	14598	6181	6181	130270
Actual growing stock (m^3)		2492625	4893904	4791079	4712755	3313261	1838449	22042073
Norm. growing stock (m^3)		2640217	5233629	7175403	6173106	3147305	3391336	27760996

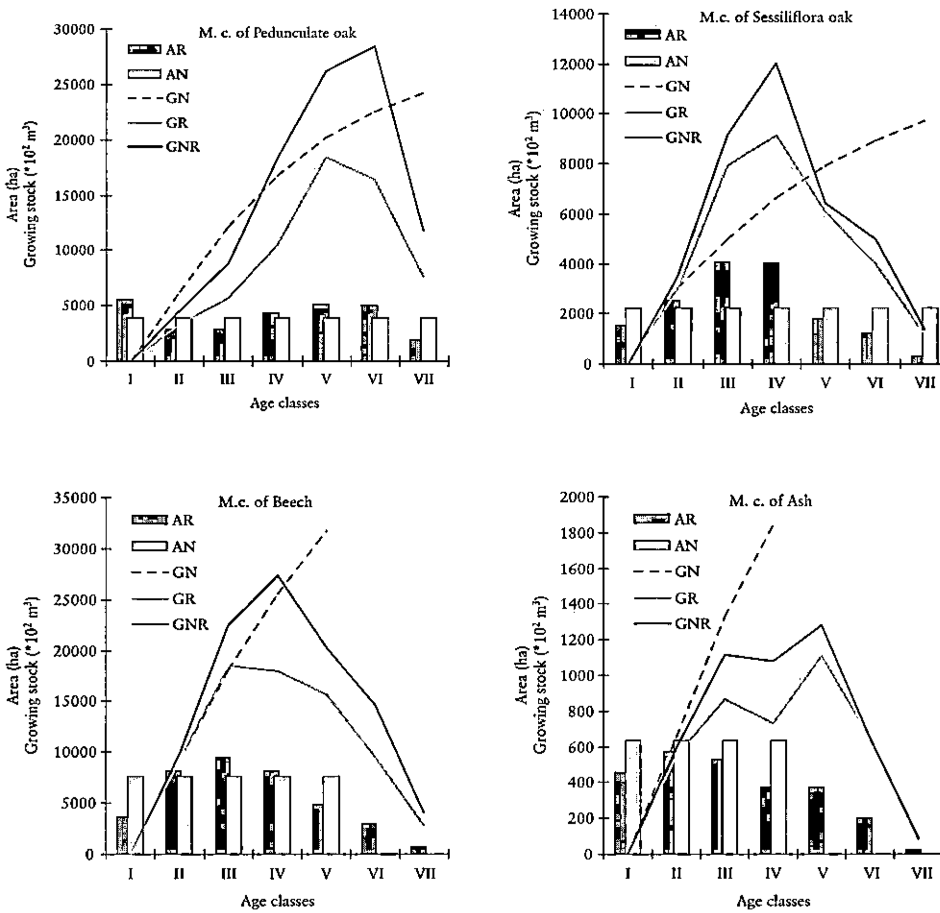
Comparison of the current and normal state per management classes reveals an irregular age structure and a reduced stand stocking. This is particularly prominent in the best-represented management classes of beech and pedunculate oak. The result is that the total normal growing stock in the management class of pedunculate oak exceeds the actual one by almost 4, and in the management classes of beech and sessile oak by 1 mil. m^3. Since the old stands in coppice forests are over-represented, the actual growing stock of coppices is almost double than that of the normal, which means that the total growing stock of 22.04 mil. m^3 in Zagreb County is less than the normal (27.76 mil. m^3) by 5.72 mil. m^3.

DISCUSSING FUTURE MANAGEMENT WITH FORESTS
RAZMATRANJE BUDUĆEG GOSPODARENJA ŠUMAMA

General guidelines of future management are based on achieving a normal age structure and stocking in stands, on transforming coppice silvicultural forms into high ones and on increased and sustainable production of general benefits from fo-

Figure 2. Actual and normal age structure per area and growing stock for the most important management classes

Slika 2. Stvarna i normalna dobna struktura po površini i drvnoj zalihi za najznačajnije uređajne razrede



rests and timber. The stability and diversity of the ecosystem in the complex region of Zagreb County should be preserved.

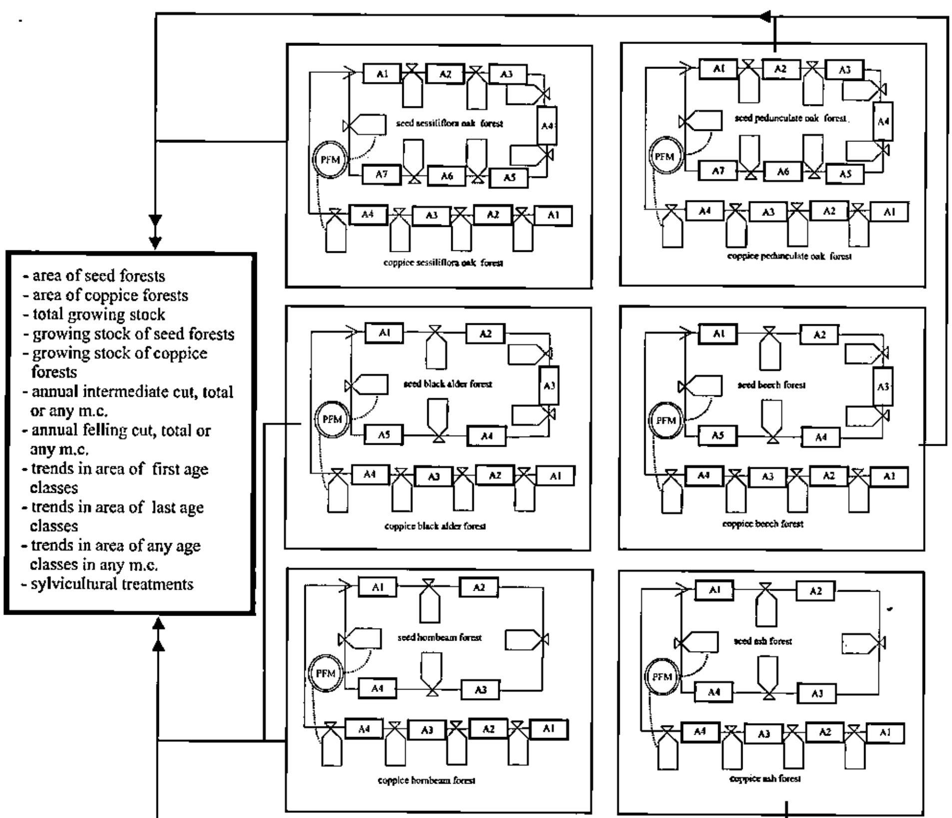
MAIN MANAGEMENT GUIDELINES IN MANAGEMENT CLASSES
GLAVNI CILJEVI GOSPODARENJA PO UREĐAJNIM RAZREDIMA

Along with high ecological functions and social benefits provided by the most valuable forests of pedunculate oak and sessile oak, the goal of management is to produce high quality oak-wood, particularly veneer and saw logs of large dimensions and fine structure. Management goals will be achieved with long rotations, the shortest 140 years, with the application of intensive silvicultural treatments of tending and cleaning in young stands: thinning in the stands aged 20 to 130 years; the shelterwood method in two cuts.

In the management class of beech, pure and mixed stands of beech and sessile oak should be managed with the rotation of 100 years. Regeneration should be conducted with the shelterwood method in two cuts. The quality and stability of the stands should be increased with regular tending, cleaning and thinning operations.

In the management class of ash, pure stands of ash should be managed with the rotation of 80 years. Regeneration should be conducted with the shelterwood method in two cuts. In order to achieve technically and aesthetically valuable ash

Figure 3. System dynamic model of the commercial forests in Zagreb County region
Slika 3. Sustav dinamički model gospodarskih šuma Zagrebačke županije



wood, intensive silvicultural treatments of tending, cleaning, protecting from game and thinning should be applied to the stands.

The stands of hornbeam, both pure and mixed with other deciduous trees should be managed with the rotation of 80 years. These stands should be supported in order to increase the stability and diversity of the forests in the entire region.

Within the management class of black alder, there are mostly even-aged, pure stands of black alder from seed or those mixed with other soft broadleaved species. The stands should be managed with the rotation of 50 years. Natural regeneration in alder stands can be achieved with the shelterwood method accompanied with preparing the site or planting seedlings.

The stands of coppice forests with rotation periods of 40 years should be managed with clear and shelterwood cuts and should gradually be conversed into seed forests.

THE PROJECTION OF FUTURE DEVELOPMENT OF THE FOREST SYSTEM BY THE SD MODEL
PREDVIĐANJE BUDUĆEG RAZVOJA ISTRAŽIVANOG SUSTAVA ŠUMA POMOĆU SD MODELA

The entire forest system of the studied area consists of 12 sub-systems made up of management classes cited above. This system can be presented with the system dynamic modelling (Čavlović 1999).

The subsystems, which are dynamic systems by themselves, especially those of high and coppice forests within the same management class, are regulated by cause and consequence links defined by the chosen management form.

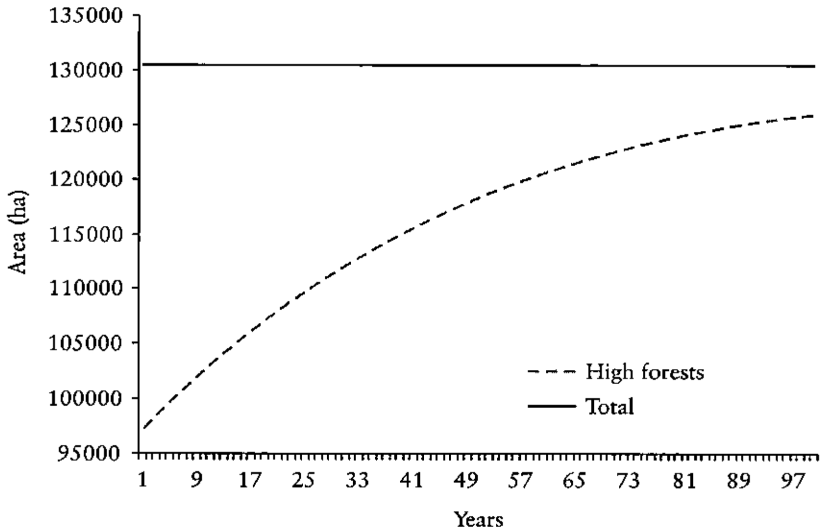
By implementing the set management guidelines and goals and by using the SD model, it is possible to obtain the future behaviour of the entire system or individual parts of the forest system in the studied area. Figure 3 shows a simplified model of a commercial forest system in Zagreb County region.

Some basic elements in the future behaviour of a part or the entire system can be shown on the basis of simulation results, within consistent implementation of the given scenarios.

TRENDS IN THE AREA
KRETANJE POVRŠINA ŠUMA

Although it is possible to show trends in the age structure per area for each management class with simulation results, only the trends in the area of seed forests within a total forest area will be given here for lack of space. The total forest area was assumed to be unchanged. The figure shows an increase in the area of high forests as a result of transforming coppice forests within the same management classes into a high silvicultural form. Thus, the area of high forests increased from initial 97,000 to 127,000 ha by the end of the simulation period at the expense of coppice forests.

Figure 4. Trends in the area of high forests in relation to the total forest area
Slika 4. Kretanje površine visokih šuma u odnosu na ukupnu površinu šuma



TRENDS IN THE GROWING STOCK
KRETANJE DRVNE ZALIHE

The conversion of coppice forests into high silvicultural forms, trends in age class distribution per area, the achievement of the normal age structure and normal stand stocking as the most important elements of future management have influenced the growing stock per age classes within management classes and that of the entire forests. Trends in the total growing stock for the entire forest and for high forests in all are shown here (Figure 5). The difference between the two shown curves is the trend in the growing stock of coppice forests. As seen from the figure, the total growing stock increases gradually, more rapidly at first and more slowly later, from the initial 23 million m^3 to 30.8 million m^3. Thus, the normal growing stock of 27.8 million m^3 from the beginning of the period was exceeded by the end of the period since the area of high forests increased by 30,000 ha at the expense of coppice forests. This means that with consistent management, the total growing stock would not only reach the level of the normal stock defined at the beginning of the period, but would also increase additionally by 3 mil. m^3 through the conversion of coppices into high forests. Within the total growing stock, the growing stock of high forests has increased from 18.8 million m^3 to 30 million m^3 as a result of a reduced growing stock in coppice forests.

Figure 5. Trends in the growing stock of high forests in relation to the total growing stock
Slika 5.. Kretanje drvne zalihe visokih šuma u odnosu na ukupnu drvnu zalihu

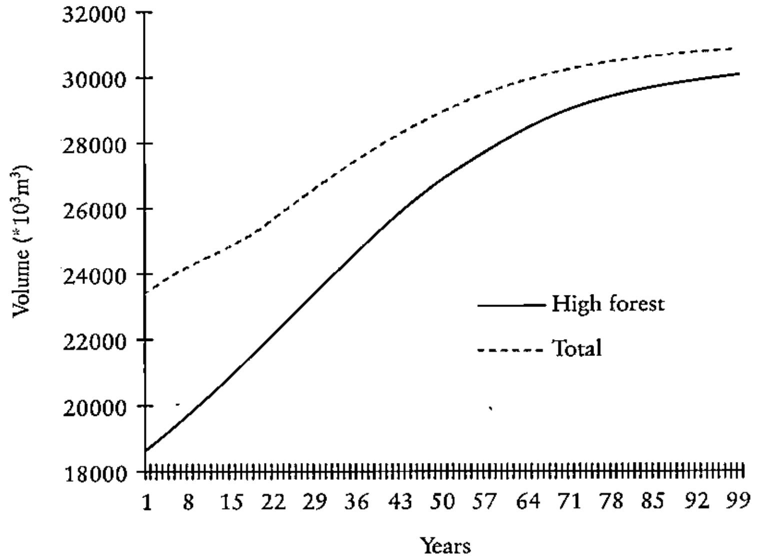
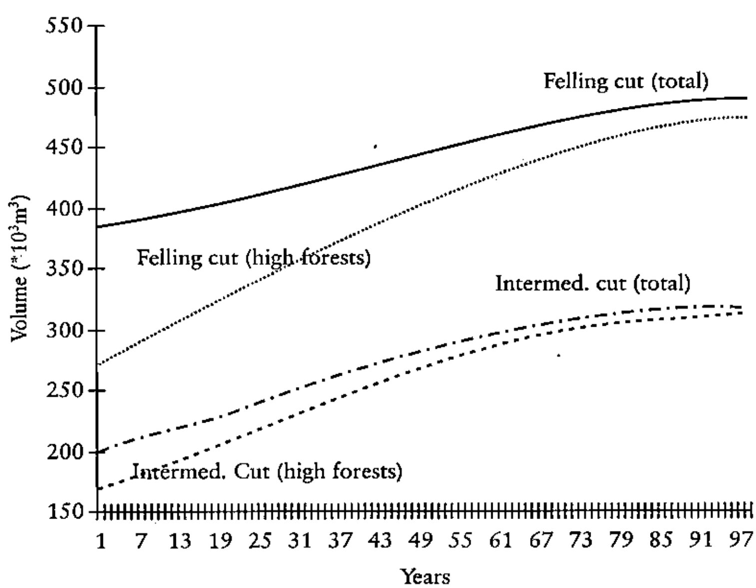


Figure 6. Trends in the annual cut
Slika 6. Kretanje godišnjeg etata



TRENDS IN THE TOTAL ANNUAL CUT
KRETANJE UKUPNOG GODIŠNJEG ETATA

Trends in the area structure, age structure, and growing stock have reflected on the trends in the total annual cut. Within assumed management in the SD model, the expected trends in the total annual cut are shown in the Figure 6. The annual felling cut is expected to rise gradually from 385,000 m^3 to 485,000 m^3, while the annual intermediate cut will rise from 200,000 m^3 to 315,000 m^3. The rise of the total annual cut in high forests in a beginning is intensive as a result of transforming coppice forests into a high forests.

TRENDS IN THE ANNUAL FELLING CUT AREA, THE AREA OF YOUNG STANDS IN THE FIRST AGE CLASS AND THE AREA OF MATURE STANDS IN THE LAST AGE CLASS

KRETANJE GODIŠNJEG POVRŠINSKOG ETATA GLAVNOG PRIHODA, POVRŠINE MLADIH SASTOJINA PRVOG DOBNOG RAZEDA TE POVRŠINE ZRELIH SASTOJINA ZADNJEG DOBNOG RAZREDA

Trends in the annual felling cut area, the area of young stands in the first and last age class at the level of the entire area are important in planning silvicultural treatments.

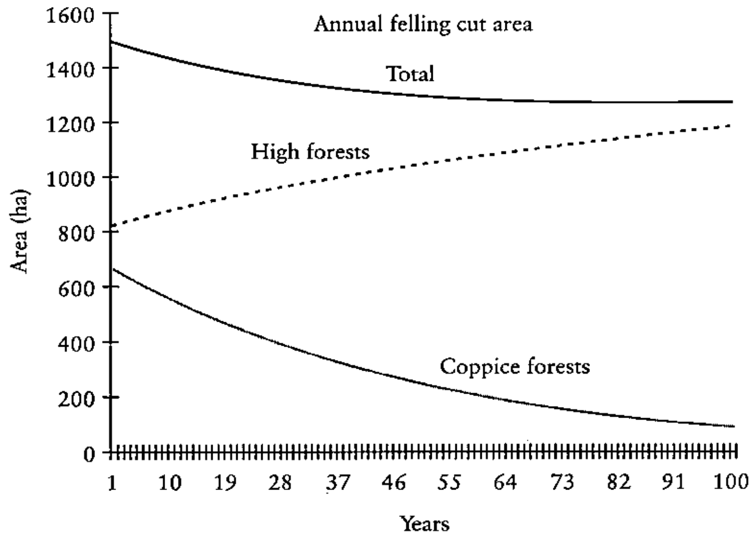
Preparation of the site for natural regeneration, repair sowing and planting with seeds and seedlings and tending young growth depend directly on the annual felling cut area. At the level of the entire region, the annual felling cut area will drop gradually from 1,500 ha to 1,270 ha. Such trends in the annual felling cut area consist of a slow rise in high forests (830 to 1,190 ha) and a stronger drop in coppice forests (680 to 90 ha).

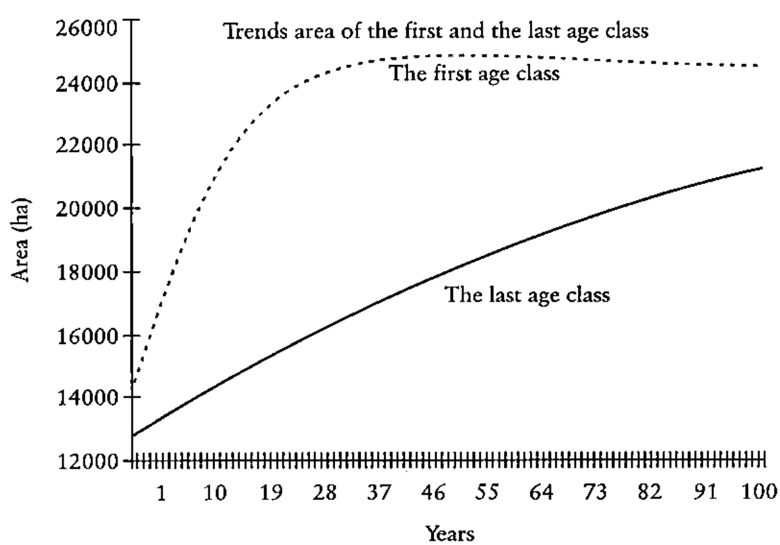
Trends in the area of the first age class are largely connected to silvicultural treatments (tending of seedlings and young growth, cleaning of stands at pole and sapling stages). According to the figure, during the first 30 years a very intensive rise from 14,500 ha to 24,800 ha may be expected in the area of the first age class, later to remain at the level of about 24,000 ha. This rise in the area of the first age class is partly the result of regeneration and the conversion of coppice forests into high forests. An equal rise in the quantity of mentioned silvicultural treatments may be expected.

Trends in the area of mature stands (the last age class) have a direct impact on silvicultural treatments to a small extent, but the information on the relationship and balance between old stands and stands in the initial developmental stages is also very important. As seen from the Figure 7, an equal and consistent rise in the area of mature stands from 12,800 ha to 21,300 ha can be expected.

Figure 7. Trends in the annual felling cut area, the area of young stands in the first age class and the area of mature stands in the last age class

Slika 7. Kretanje godišnjeg površinskog etata glavnog prihoda, površine mladih sastojina prvog dobnog razreda te površine zrelih sastojina zadnjeg dobnog razreda





CONCLUSIONS
ZAKLJUČCI

Forest areas are very significant features of Zagreb County for a variety of reasons. These are: very dense population, growing demands for forest functions of general benefit, rich diversity and multiple uses of forests, and the need to re-establish the disturbed stability of forest ecosystems.

In this region forests of beech, pedunculate oak and sessile oak are the most significant. Apart from their high ecological and social values, they are used for the production of high quality oakwood.

In terms of the irregular age structure of the forests and stand stocking according to the existing growth-yield tables, the growing stock of all the forests in the region is lower by 5.72 million m^3 compared to the normal state.

General guidelines of future management are based on achieving a normal age structure and stocking in stands, the conversion of coppice forests into high ones, the higher and sustainable production of both general benefits from forests and timber and the preservation of ecosystem stability and diversity.

Future development of these forests may be predicted with the SD model on the basis of defined guidelines. This can serve as a basis for rough long-term planning at a regional level. In terms of trends in the area, growing stock and prescribed yield, the results of simulation have shown that significant potential productive capacities of these forests may be achieved with consistent management.

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GOSPODARENJE ŠUMSKIM DOBRIMA U ZAGREBAČKOJ ŽUPANIJI

SAŽETAK

Zagrebačka županija zauzima 3720 km^2, vrlo je gusto naseljen i razvijen prostor kada se uzme u obzir i Grad Zagreb. Zbog naglašene opterećenosti ovoga prostora značenje i funkcija šuma su vrlo veliki. U radu se daje prikaz postojećega stanja šuma i šumskoga zemljišta s obzirom na strukturu vlasništva, namjenu šuma, strukturu po vrstama drveća, uređajnim razredima, dobnu strukturu po površini i drvnoj zalihi, te potencijalne proizvodne mogućnosti. Šumom obraslo šumsko tlo nalazi se na 139 275 ha, od čega su panjače na 35 027 ha (2,6 %), i to uglavnom u okviru privatnih šuma. Šikare se nalaze na 1 419 ha, dok neobrasloga proizvodnoga šumskoga zemljišta ima samo 1 757 ha. Gospodarske šume zauzimaju površinu od 136 650 ha s 22,31 mil. m^3 drvne zalihe, koja godišnje priraste 750 000 m^3 (6,38 m^3/ha). Iako šume i šumsko zemljište zauzima 1400 km^2, što je 46,7 % ukupne površine Županije, gospodarenje šumskim resursima mora voditi povećanju potencijalnih proizvodnih mogućnosti svih dobara. Uz podršku SD modela na temelju definiranih smjernica gospodarenja u članku je prikazan predvidivi budući razvoj tih šuma. To može poslužiti kao osnova za gruba dugoročna planiranja na razini regije. S obzirom na prikazano kretanje površina, drvne zalihe i sječivoga prihoda, rezultati su simuliranja pokazali da bi se uz dosljedno gospodarenje moglo očekivati postizanje značajnih potencijanih proizvodnih mogućnosti tih šuma. Povećanje površine visokih šuma za 30 000 ha, povećanje drvne zalihe za 7,8 mil. m^3, povećanje godišnjega sječivoga prihoda za 215 000 m^3, povećanje šumskouzgojnih radova – neke su od osnovnih značajki budućega gospodarenja.

Ključne riječi: gospodarenje šumama, razmjer dobnih razreda, smjernice budućega gospodarenja.

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