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UDK: 630*624

Original scientific paper
Izvorni znanstveni članak

MANAGEMENT MODELS APPLIED TO FIR FORESTS IN GORSKI KOTAR

PRIMJENA MODELA PRI UREĐIVANJU JELOVIH ŠUMA GORSKOGA KOTARA

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Received – *Prispjelo*: 15. 1. 2001.

Accepted – *Prihvaćeno*: 22. 11. 2001.

Fir forests in Gorski Kotar have been managed with different models, the majority of which are derived from the normal method. Models resulting from the Normal Method Before and After Cutting (prescribed by the Instructions of 1903), as well as Klepac's "New System of Managing Selection Forests" and the Institute's EMTs (ecological-management types), have been used since the beginning of management with these forests.

It is clear from the position of tree number curves in "old" normal models (which represent the correction of the condition in the forest) and in the normal model of the studied EMT I-C-10b in relation to adequate Klepac's normal models that in the majority of old models the curve of the tree number is above Klepac's curve, with more significant deviations occurring (in %) in lower and higher diameter classes. This is the consequence of the condition of these forests at the time of management (the end of the nineteenth and the first several decades of the twentieth century), when these forests contained excessive growing stock resulting from extensive management. One part of these models was constructed under an unrealistic assumption that the basal areas of all diameter classes were equal. It is for this reason that the deviation of these models from the model by Klepac is the most distinct in the lowest diameter classes. It is interesting that the deviation in percentages of the Institute's normal model EGT I-C-10b, adjusted to pure fir condition before cutting, almost completely coincides with Jovanovac's normal model for the land community Benkovac from 1912. This model was made under the assumption of the equality of basal areas of all diameter classes.

Furthermore, within this EMT, represented by one model, there were stands with a wide range of quality classes, fir I/II-IV and beech II-V. Based on these facts, the use of original Klepac's normal models is recommended for managing fir selection forests. In this way, an artificial lowering of the heights of dominant trees (the result of cutting the trees above a certain maturity dimension and different ways of defining dominant heights used by some authors) will be avoided (Božić & Čavlović 2001).

Based on the position of the curves of tree numbers from different years of measurement and on their position towards the proposed model, it is possible to draw conclusions on the condition of a stand's managed status and to determine the trends of a given stand in relation to the proposed model. This, along with the record of the completed activities, may greatly assist in the future management of these stands. The proposed model by Klepac should be regarded as a transitional model rather than a permanent one until a more favourable model is found through management activities.

Key words: Gorski Kotar, forest management, models

INTRODUCTION
UVOD

The forests of Gorski Kotar are well managed and easily accessible. A good and dense network of forest roads enables intensive forest management based on management plans that are revised every ten years and reviewed every twenty years.

From the first management plans to date, the forests of Gorski Kotar have been managed with different methods set down in a number of instructions, directives and regulations that followed both foreign and Croatian scientific and specialist insights.

Models of forest management primarily refer to the ideals to be attained using a management method.

The first models used to manage the forests of Gorski Kotar and Kapela date from the end of the 19th and the beginning of the 20th century. They were the result of the normal method before and after cutting (Miletić 1951). This method was prescribed in the Instruction of 1903 (Anon. 1903) for the management of selection forests of particular public interest. According to the Instruction, a typical stand should contain the number of trees, the sum of basal areas and the growing stock (based on the concrete state in a forest) that would normally be found in one *ral* (5,754.642 m^2) of a selection forest before and after cutting.

In case of selection forests, the total number of trees, the size of the basal area or the growing stock per ha to be achieved cannot be considered a model.

In order for some of the above structural elements to be regarded a model, their internal structure or the distribution by degrees (classes) should be taken into account.

Based on the Forest Law of 1929, the "Instructions for State Forest Management" were issued in 1931, which prescribed the control method for managing selection forests (Klepac 1997).

In this method, the model is not set beforehand, but is established in the course of management. As this method was not applied in practice due to extensive management, there are no data on the achieved "managed models".

The "Instructions for tree consignment and revenue definition in selection forests" were issued in 1937 as a reaction to the inability to apply the control method. The Instructions were based on the minimal growing stock to be retained in a forest after cutting.

The method of minimal stocks to be retained after cutting resulted in the graphs of the stands in which cutting was considered successful. These graphs were kept in the records and used as models in defining the structure or the curve of growing stocks after cutting in similar stands; nevertheless, they did not actually represent a model.

Models most commonly refer to the models resulting from the normal method.

With his "New System of Managing Selection Forests", Klepac (1961) reintroduces the normal method into the management of selection forests. Klepac himself states in his "New System ..." that normal models have a temporary character, as he intends to study normal models by forest types. However, normal models by forest types were not made by Klepac as was his intention, but by the staff of the Forestry Institute in Jastrebarsko headed by Cestar. They adapted the existing normal models to forest types (according to Križanec 1987).

Since the issue of the "New System" in 1962, the forests of Gorski Kotar have been managed with the normal model by Klepac (New System ...), and in the period 1968-1994 also with the Institute's normal models according to the EMTs.

The present condition of these forests and their final managed status with the existing models is the direct consequence of past management with these forests. Management has not been uniform. Apart from some general trends, different forest owners managed their property in different ways following the then valid legal regulations. For better understanding, I will give a historical survey of forest ownership, discuss past management with these forests and list the methods and legal regulations relating to the management of these forests.

RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

The research was conducted in the area of Gorski Kotar.

Geographical position - Gorski Kotar is located in western Croatia; in the north and north-west it borders with Slovenia, in the south-west and south with the Croatian Littoral, and in the east with the Ogulin area. The northern, north-western, south-western and southern boundaries of Gorski Kotar are defined by natural and political-administrative boundaries, but those in the east are not so clearly defined.

Geological structure - Almost all the rocks in Gorski Kotar belong to a large group of sedimentary rocks, with the prevalence of limestones and dolomites.

Pedological features - Several main soil groups are developed in Gorski Kotar: gleysol on limestone, rendzina on dolomite, cambisols on limestone and dolomite, acid cambisols, illimerised soils on limestone, brown podzol soils and podzols and arable soils.

Climate - According to Köppen's classification, the entire area of Gorski Kotar belongs to the Cfsbx" type of climate, except the part above 1,200 m, which belongs to the Dfsbx" climate type (Seletković & Katušin 1992).

Plant communities - The north-easternmost part of Gorski Kotar is a hilly region reaching about 400 m above sea level. It is basically characterised by different oak stands. The major part of the area lying between 400 and 1,100 m above sea level contains vast forests of beech and beech and fir on different petrographic substrates. In terms of orographic, climatic, ecological-phytocoenological and forest management differences, the montane area is divided into lower and higher parts. The lower montane area is covered with pure beech forests, which follow the forests of sessile oak and common hornbeam (from the mainland) or hop hornbeam with autumn sesleria (from the littoral) hilly area. The principal physiognomic and ecological-vegetational features of the higher part are the self-growing, mixed or pure, coniferous forests, mainly fir and spruce, which grow abundantly. In terms of height, this area is located between the climatozonal regions of hilly and sub-mountainous forest of beech. The pre-mountainous area covers the highest positions in the Risnjak, Snježnik, Burni Bitoraj and Bjelolasica massifs about 1,000 m above sea level (Bertović & Martinović 1981).

SUBJECT OF RESEARCH
PREDMET ISTRAŽIVANJA

The research deals with fir forests in Gorski Kotar.

Fir forests are forests of the high silvicultural form with a mainly uneven-aged composition. They are managed selectively.

According to Schütz (2001), a selection forest is a forest made up of trees whose lateral crown sides are not in contact as a rule, but they nevertheless fill up the total vertical growing space.

The ideal selection structure of a forest is represented by trees of different heights and diameters in an area unit, in which the normal growing stock is distributed in a selection structure that ensures maximal increment, optimal natural regeneration and stability (Matić *et al.*, 1996).

A selection forest is the result of regular and systematic selection management over many years.

According to Korpel (1996), the characteristic selection structure and a balanced selection forest is not a natural phenomenon, but a consequence of systematic planned forest management, that is, of systematic selection cutting.

Pursuant to Article 4 of Forest Management Acts of 1994 and 1997, a selection forest is composed of differently-aged stands. Article 9 of the same Acts states that differently-aged stands are stands containing trees of variable heights, diameters and ages that are regenerated naturally. They may be managed with the single tree or group selection systems.

The *single tree* management system is used in stands on karst terrain with little soil, where the soil requires continuous protection from adverse abiotic factors, which frequently occur in an extreme form.

The *group* management system is applied to the stands inhabiting mild slopes with abundantly deep, nutrient-rich and moist soils. The diameter of groups ranges from 1-2 height of the tallest trees in a stand. The area supports trees of approximately equal diameters and heights.

Apart from these two methods of selection management, until the 1994 Forest Management Act, a *cluster* management method - groups with diameters higher than two heights of the tallest trees - was also envisaged. The areas in question contain trees of approximately equal diameters and heights. Groups become clusters and the bigger they grow the further away we depart from selection management and approach the regular one.

Related to cluster management, Prpić & Seletković (1996) say: "The application of cluster management method in the areal of beech-fir forests disrupts the selection structure, which is against the natural management method and represents a mistake both from ecological and biological standpoints, and consequently from the economic standpoint."

The Forest Management Act of 1994 excludes the possibility of the cluster selection management.

In the area of Gorski Kotar, fir occurs in three plant communities and forms: the Dinaric beech-fir forest (*Omphalodo-Fagetum* Marinček *et al.* 1992), fir forest with blechnum (*Blechno-Abietetum* Ht. 1950), and fir forest with reedgrass (*Calamagrostio-Abietetum* Ht. 1950) (Vukelić & Baričević 2001).

In Gorski Kotar, fir occurs in the following EMTs (ecological-management types): I-B-11, I-C-10b, I-C-11, I-C-12, I-C-40 and I-C-61 (Klepac 1997).

Based on the regulations of the 1994 Forest Management Act, forests are classified according to management classes. The 1996 Forest Management Plan of the area states that fir forests are placed in two management classes (MC): MC of fir and beech and MC of fir and spruce. The total area of fir forests in Croatia, from the same source, is 220,000 ha, of which about 100,800 ha or 46% are in the area of Gorski Kotar.

These two management classes account for 80% of the total forested area of Gorski Kotar.

THE OWNERSHIP STATUS OF THE FORESTS IN GORSKI KOTAR
VLASNIŠTVO NAD ŠUMAMA GORSKOGA KOTARA

The majority of the forests in Gorski Kotar belonged to the dukedoms of Brod, Čabar and Grobnik in the form of feudal holdings. They were first owned by the dukes of Krk, the Frankopans and the Zrinskis, and from 1572 the whole of Gorski Kotar became the property of the counts of the Zrinskis.

Following the death of the Frankopans-Zrinskis in 1671, their property was confiscated by the Austrian state. A part of the property came under state ownership, while the other, smaller part was donated to individual noblemen by royal deeds. Over the years, the property changed hands and was owned by different families (Perlazs, Batthyanyi, Paravić). In the 19th century, the entire area was the property of two aristocratic families: the German dukes of Thurn-Taxis

(1872) and the Hungarian barons Ghyczy de Ghyczy Assa et Albanczkürth (1866).

Upon the abolition of feudalism, a part of pastureland and forests belonging to feudal lords was given to former serfs (on several occasions). These forests established the grounds of land communities.

Based on the Land Reform Act of 1931, at the request of the municipalities, the forests of major landowners in Gorski Kotar were expropriated in 1932 (about 43,600 ha). Thurn-Taxis lodged a complaint in 1932 and the state returned the biggest part of the expropriated property to him and to Ghyczy by the 1939 Agreement.

The forests belonging to the state and to landed gentry formed large entities. The forests of land communities were mainly located at the edges of these complexes, or were enclaves in private ownership. They were located in the vicinity of the villages to which they belonged.

After World War II, all forests except those of small owners (so-called maximums) were proclaimed the national property. The maximum for the forests in hilly regions ranged from 15-30 ha. Land communities were abolished in 1947.

Since 1945 to date, the forests of Gorski Kotar have been managed by various forest administrations. Since 1991, they have been a component part of the Public Enterprise "Croatian Forests" Zagreb, and belong to the Forest Administration Delnice in their major part.

PAST MANAGEMENT WITH THE FORESTS OF GORSKI KOTAR
DOSADAŠNJE GOSPODARENJE ŠUMAMA GORSKOGA KOTARA

Past management with these forests has left considerable imprints on the development and the condition of forests as dynamic live organisms.

Different owners (in the past) managed their forests in different ways, and the present state of these forests is the result of their activities.

The end of the 17th century saw the beginning of exploitation of the forests near mines, sawmill, mills and similar.

New roads and the railroad led to a more intensive exploitation of Goranian forests, but again only those near these communications links. Felling activities did not affect the deeper parts of the forests, and so the majority of the area was left in its virgin form.

With reference to the forests of Gorski Kotar in mid-nineteenth century, Frančišković (1965) says that almost half of these forests were on the verge of ruin, and that the remaining, bigger part, consisted of inaccessible virgin forests in which any exploitation was impossible. At that time, the basic management postulate was irregular selection cutting. According to Šurić (1933), regulated selection cutting only began in 1926.

The selection method of management developed at the end of the 19th century in Central Europe and in Croatia (Matić 1990). At that time, some notions of regular forests were used in managing these forests: age classes, sporadically scattered over the area; rotation, divided into a certain number of cutting cycles. Rotation represented the number of years needed by a tree to achieve cutting maturity.

Tichy recommends the introduction of diameter classes. Hufnagl (1892) abandons rotations completely and introduces cutting cycles instead (Kern 1989).

Management plans from the end of the nineteen century prescribed selection management for these forests.

Selection management as a forest-management form had strong opponents, especially from the ranks of those advocating a pure land income (Frančišković 1938b). As a result, at the end of the 19th century and the beginning of the 20th century, selection management was abandoned in some state forests and in the forests owned by Thurn-Taxis in Gorski Kotar to be replaced by inexpert stereotypical shelterwood cutting with 120-year rotations and short 20-year regeneration periods. Good quality trees were cut, while overmature trees of poor quality were left. Regeneration did not take place in the planned period, and final cuts could not be carried out. For this reason, the introduction of the shelterwood cutting method in high forests on karst was harshly criticised, to be prohibited in 1919 (Milković 1979). Selection management was reintroduced, but the lost selection structure serves as a relic of the shelterwood system.

Up to the Second World War, every forest owner managed their forests in their own way. The forests owned by Thurn-Taxis were managed with a lower intensity (extensively). The focus was on hunting management, and only some small and local cutting procedures were applied. Roads were designed and built primarily for the purposes of hunting. Large amounts of growing stock, consisting mainly of mature and overmature trees, were retained in stands (in some places over 1,000 m³/ha), and regeneration was neglected.

After the Second World War, the stands mostly had the form of a disorderly selection forest type, and types of almost even-aged stands prevailed. True, all diameter classes were represented, but generally with an insufficient number of trees in thinner diameter classes, and an excessive number of thick, mature and overmature trees, which was the consequence of earlier management with these forests.

The forests owned by Ghyzy were managed with higher intensity (intensive). The stands were exploited rationally and no stocks of overmature trees were kept in them.

After World War II, the structure of these stands was approaching the selection one, while some of the stands had pure selection structures.

At that time, the forests managed by land communities resembled those formerly owned by Thurn-Taxis in terms of management intensity.

As was mentioned earlier, beech was cut intensively over the whole period, partly because its products, charcoal and potash (as well as the sleepers for the railroad under construction - from one part of the forests) were in high demand on the market, and partly because these forests were managed with Pressler's theory of pure land income with the interest of 3%. Consequently, conifers were favoured.

Beech was considered a species of the "inferior order". According to Frančišković (1938a), taxation activities included only fir together with spruce, while beech was not measured but only assessed ocularly.

The treatment of beech is best exemplified by the fact that, according to a paper from 1867, in the area of the Batthyany estate (later the estate belonging to Thurn-Taxis), beech accounted for about 67% of all the trees. In 1907, there were 54% of the beech, while at the end of the second decade of the 20th century, it accounted for 34%. Beech was radically removed to make as much space as possible for fir. This took such proportions that in places where beech could not be marketed well, trees were girdled in order to accelerate their death so that they would not cast shade over young firs. Other hardwoods were treated similarly.

According to Šafar (1968), after World War I the fear of agrarian reforms by large landowners resulted in more intensive cutting of the more profitable fir.

Forests themselves did not suffer too much harm during the Second World War. The trees along the roads and the railway line were clearcut in order to make traffic safer, but the trees deeper in the forests were not cut.

The years after World War Two bear witness to large-scale cuttings in Gorski Kotar, partly for the needs of rebuilding the country and partly for export. In 1948, as much as 1,105,166 m³ (846,903 m³ of conifers) were cut, in 1949 the amount of 914,234 m³ (626,843 m³ of conifers) was felled, while in 1950, the quantity of 703,466 m³ (460,411 m³ of conifers) was cut (Navratil 1981). In comparison, in the period 1946-1960, the amount of 433,170 m³ was cut annually on average (275,542 m³ of conifers) (Navratil 1981), while in the period 1986-1995, the average annual cut was 470,918 m³ (280,360 m³ of conifers) (Klepac 1997).

As the majority of the stands at that time contained large amounts of growing stock, the problem was not its quantity as much as the method of its exploitation.

The management plan for the management unit (MU) "Milanov Vrh" for the period 1960-1969, in the management records, page 15, says: "Forest rangers and others in charge of consignation were inadequately educated for the most part and therefore did not pay attention to silvicultural issues in selecting trees. Felling teams consisted of people who were not trained to do forest jobs and thus did not follow forest orders. Frequently, unmarked trees were cut, while marked ones were left standing. It was the technique that was important. Due to the above, overmature trees lacking any technical value were left in the stands, and now silvicultural reasons force us to keep them there."

In the difficult political situation (the conflict with Stalin) in 1948, the shelterwood cutting method was proposed for more accessible areas in order to ease the transport from felling areas and increase the concentration of cutting stock over a smaller area. After lengthy discussions, a firm opinion of an expert commission was accepted stating that the single-tree silvicultural felling should be and remain the basic guideline in forest exploitation.

Most forests in Gorski Kotar today are of different ages (neither selection nor regular). There are also well regulated selection forests of fir and beech, such as, for example the forests of the MU "Lividraga, MU "Milanov Vrh" and some privately owned forests around Prezid (Klepac 1997).

Currently, the biggest problem of selection forests in Croatia is their lost selection structure, characterised by an excessive number of trees in higher diameter classes and an insufficient number of trees in lower and medium diameter classes.

The lost selection structure is the result of too long cutting cycles, that is, of an overabundant growing stock per hectare (Matić *et al.* 1996).

METHODS OF MANAGING FIR FORESTS IN GORSKI KOTAR
METODE UREĐIVANJA JELOVIH ŠUMA GORSKOGA KOTARA

Management with forests in Gorski Kotar was regulated by different acts, instructions and decrees, which prescribed management ways and methods.

Method - a way of proceeding or doing something; a system, a planned activity undertaken with the aim of achieving a certain goal in a practical or theoretical field (Klaić 1989).

Mention should be made of the following acts regulating forest management up to 1769: the Krk Statute from 1388; the Verboczius's *Tripartitum* from 1514; the *Urbar* by Maria Theresa from 1755; the "Forest Order of the Trieste Commercial Intendance" from 1767 in the German and Italian languages (Klepac 1976).

In 1769, Maria Theresa issued a "Legal Forest Order" in the Croatian language. This Order prescribed a method of dividing forests into annual coupes. The envisaged rotation for the fir and spruce was 80 - 100 years and for the beech 120 - 150 years. The method consisted of the following: a forest was divided into as many parts (coupes) of approximately equal size as the number of years in a rotation. Every year one part was cut, and the coupes followed successively one after the other. At the end of the rotation, the whole forest was cut. Then the cutting resumed in the same place in which it had began.

In 1788 the forest order for the Kingdom of Hungary was issued, which also served as a basis for managing the forests in Gorski Kotar.

In 1798, Matija Josip Paravić, a landowner, issued an instruction on the principles of management in the Čabar estate.

The Forest Law of 1852 came into force in Croatia on January 1, 1858. According to this law, forests were divided into three categories: state, municipal (town, village, etc.) and private. Forest management was also prescribed. Paragraph 9 of this law mentions a management plan determining the cutting method and the quantity in the forests burdened with "forest usufructs".

An "Instruction for measuring, assessing and managing forests in income communities of Croatian-Slavonian *Krajina*" was passed in 1881. According to this instruction, the annual prescribed yield was determined applying the formula of the Austrian cameral tax. The basic purpose of this method was to establish a normal growing stock in a forest so that the principle of sustainable management was ensured.

The 1894 "Law prescribing expert administration and forest management in forests of particular public interest" explicitly stated that forests of particular public interests were to be managed in a sustainable manner on the basis of management plans or programmes. Forests of particular public interest were forests of land communities and income municipalities, as well as church, town and communal forests. Based on this law, in 1903 an "Order on drawing management plans and programmes and proposing annual harvesting and silvicultural practices" was passed, whose component part was the "Instruction for drawing management plans or programmes" A large number of management plans were based on this Instruction, because it was valid until 1948.

The "Instruction" of 1903 hardly treated the problem of selection forest management, although forestry practice of the time had mastered the problem of managing selection forests.

The "normal method" was prescribed for managing high selection forests (Meštrović 1987).

According to the "Instruction", the normal model had to be constructed for every management unit to serve as a management paragon or *model*.

State forests were managed (until 1931) on the basis of foreign instructions (Austrian and Hungarian).

According to Klepac (1997), until 1919 the majority of the foresters in the state forests of Gorski Kotar were Hungarians. Accordingly, they managed the forests there using the Hungarian instructions.

Based on the Forest Law of 1929, "Instructions for managing state forests" were passed in 1931, which prescribed the control method for managing selection forests.

The control method was based on systematic single-tree and repeated stock inventories, combined with accurate records of the stock utilised in the meantime. This made it possible to calculate the current increment directly, which was an important indicator for predicting future cuttings. Particular attention was paid to determining whether the cut stock per ha was too high or too low, what the tree species mix was, what the participation percentage of different diameter classes was and whether any changes were needed in that respect (Križanec 1963).

The control method, as an intensive management method, could not be applied successfully at the time when the forests were managed extensively.

For this reason, as a reaction to the inability of applying the control method, the "Instructions for tree consignation and income definition in selection forests" were passed in 1937.

The Instructions were based on minimal growing stocks to be retained in a forest after cutting, shown in Table 1.

Table 1. Minimal growing stocks to be retained in a forest after cutting (Anon 1903).
Tablica 1. Minimalne drvne zalihe koje trebaju ostati u šumi poslije sječe (Anon. 1903)

Position by altitude / *Položaj po nadm. visini*	Minimal stock after cutting per ha for a site class / *Minimalna zaliha poslije sječe po ha za bonitet*						Increament per ha for a site class / *Prirast po ha za bonitet*					
	Beech - *Bukva*			Fir and spruce - *Jela i smreka*			Beech - *Bukva*			Fir and spruce - *Jela i smreka*		
	good *dobar*	medium *srednji*	bad *loš*	good *dobar*	medium *srednji*	bad *loš*	good *dobar*	medium *srednji*	bad *loš*	good *dobar*	medium *srednji*	bad *loš*
Lower *Donji*	280	230	190	480	360	290	5.6	4.6	3.8	9.6	7.2	5.8
Middle *Srednji*	230	190	150	360	290	220	4.6	3.8	3.0	7.2	5.8	4.4
Upper *Visoki*	190	150	110	290	220	160	3.8	3.0	2.2	5.8	4.4	3.2

In terms of altitude, the positions were divided into three zones: for north-western regions, closer to the sea, the lower zone corresponded to the altitudes of 500 to 800 m, the middle zone to 800 - 1200 m, and the upper zone to 1200 m up. In central and southern regions, the zones were moved upwards by 100 - 200 m.

The prescribed yield was determined graphically; the growing stock curves by diameter classes were drawn before and after cutting. Both curves were binomial. The curve of the growing stock after cutting was determined on the basis of experience in marking and the performed cutting operations (the successful ones).

Contrary to other methods, the Instructions of 1937 were original, practical and satisfactory for the conditions of the period. They provided a basis for a large number of management plans for selection forests (Klepac 1997).

The method was appropriate for that period, when the Croatian forests contained large quantities of the growing stock and when forest management was reduced to stereotyped regulation of cutting.

Klepac (1976) mentions that the 1903 Instruction was still valid for selection forests of particular public interest, causing situations in which, in the same forest area, selection forests of some land communities (in Gorski Kotar) were managed with normal models and increment measurements, in other words, much more intensively than state forests managed with minimal stocks after cutting and increment assessment.

All that time (until the Second World War), a considerable proportion of private forests was managed by foreigners, who applied Austrian and Hungarian instructions.

According to Klepac (1997), in the period between the two World Wars, about 60% of the area in Gorski Kotar was managed using foreign models, 22% of the area was managed according to the 1903 Instruction, using the principle of strict sustainability, while 16% of the area was managed on the basis of the 1931 and 1937 Instructions applying the sustainability principle.

"Temporary Instructions for Forest Inventory" were passed in 1946. Their basic task was to find the fastest possible way of assessing what was left and what the structure was of the forests in a country devastated by the war and uncontrolled cutting. The "Temporary Instructions" prescribed management of forests for the entire territory regardless of the ownership type.

In 1948, the "General Instructions for Forest Management" were passed, thus putting the 1903 Instructions and the 1933 Instructions out of use.

According to the 1948 "General Instructions for Forest Management", "to regulate forests means to measure forest land and stands, describe stands, thus establishing the condition of a forest at the time of management, and on the basis of this condition set down guidelines for future management with forests in terms of silviculture and tending, rational and permanent exploitation, and intensify forest management in general."

After World War Two up to the "New System...", selection forests were managed with the 1937 Instruction, complemented with elements of intensive management.

The increment was not assessed but measured with Pressler's drill, the quantity of satisfactory growing stock was determined, a cutting cycle of 10 years was adopted and a management method was prescribed. The prescribed yield was calculated on the basis of the relationship between a concrete and satisfactory growing stock, the general and health status of stands and the state of natural regeneration. The cutting intensity did not exceed 25% in any of the stands (Križanec 1987).

In 1961, Klepac published the "New System of Managing Selection Forests", based on normal models (optimal state).

Normal models were intended for foresters in practice as a tool for managing and regulating selection forests.

The Forestry Secretariat of the Executive Council of the Socialist Republic of Croatia put the "New System" in use with its decision no. 05-441/2 of 12 February 1962.

The "New System" has been widely used in practice and still serves as a basis for managing Croatian selection forests (Meštrović *et al.* 1992).

The "Regulation on Drawing Forest-economic Plans, Management Plans and Programmes for Forest Improvement" of 1968 prescribed ecological-management types (EMT). The EMT is determined on the basis of the geological substrate, forest community, soil type, climate, silvicultural features, productive capacities and stand values.

According to this Regulation, as well as the Regulations of 1976, 1981 and 1985, forests and forest land are classified by EMTs, and within EMTs by management classes. In management units (MU) in which EMTs are not established, until their establishment forest management goals are determined by management classes (according to the purpose of forests and the principal tree species, on the basis of which management goals, rotation, and cutting maturity are determined).

In the period between passing the "New System" in 1962 and the Regulation of 1994, the forests in Gorski Kotar were managed with the normal method. Klepac's normal models were used all the time (the "New System..."), and the Institute's normal models based on EMT were also used in the period 1968-1994.

Bertović *et al.* (1974) state that normal models by EMTs were based on the established cutting maturity in individual forest communities, the species mix found to be the most favourable and Klepac's normal models for beech and fir.

The 1994 Regulation prescribes that selection management can only be applied in fir forests in which other tree species exceed the amount of 10% of the total growing stock. The management goal and method, as well as all the ensuing activities, are determined at the level of management classes (not EMTs any more) within a management unit.

Selection (uneven-aged) forests are managed with the normal method, or according to the "New System...". The Regulation of 1977 has retained the basic postulates of the 1994 Regulation.

MODELS USED IN MANAGING FIR FORESTS IN GORSKI KOTAR

MODELI UPOTRIJEBLJENI PRI UREĐIVANJU JELOVIH ŠUMA GORSKOGA KOTARA

Model - pattern, design, mould (Klaić 1989)

The paper presents models (normal models) derived from the Normal method before and after cutting in Klepac's "New System ..." and EMTs.

THE NORMAL METHOD BEFORE AND AFTER CUTTING
METODA NORMALA PRIJE I POSLIJE SJEČE

The 1903 Instruction for the management of selection forests of particular public interest prescribed the normal method before and after cutting. Based on the Law of 1894, the "Law regulating expert administration and forest management in forests of particular public interest", some Croatian experts tried to find a method of regulating these selectively managed forests. According to Miletić (1951), the beginnings of this method are found in the works of Tvrdony (1897) and Kern (1898).

According to the Instruction, the number of trees, the sum of the basal areas and the growing stock should be determined (on the basis of the concrete state in the forest), which is normally found in 1 *ral* (approx. half an acre) (one *ral* = 5,754 m^2) before and after cutting in a selection forest.

Miletić (1957) divides normal models before cutting according to their origin:

1. Realistic - based on the data obtained from a selection forest itself.
2. Theoretical - based on certain regularities and gradualness, observed in normal stands; based on the elements collected in a selection forest under management.
3. Combined

Normal models resulting from managing Croatian forests are mostly realistic normal models. With regard to the manner of their origin, Miletić (1957) further divides them into:

1. Free normal models - obtained through the condition in smaller areas of typical stands;
   a) derived from a pure selection stand
   b) derived from a mixed selection stand
2. Deductive normal models - obtained as a mean of several sample areas;
3. Foreign normal models - normal models taken from a foreign source and adapted to the real conditions in a forest.

If a normal model could not be found in a forest before cutting due to past cutting activities or to some other reasons, foreign normal models were applied to this forest, or the normal model was constructed in the following way: in the plots in which the normal model was sought, the structural elements were measured, the forest cover was assessed, and the measured elements were adjusted to the total cover.

Since site and stand conditions in a karst area frequently change, it is questionable whether free normal models constructed on the basis of the condition in a smaller area can be considered a representative of the whole forest.

Different elements of the structure were used to construct the normal model before cutting (basal area, crown cover, number of trees).

The condition after cutting was assessed empirically by repeated tests. The entire final diameter class and a part of the trees from other diameter classes (surplus trees) were designated for cutting. Later, Majnarić abandons this rule and does not cut the whole final diameter class, but its major part (in the normal model for the forest of the former land community Drivenik, 90% of the final diameter class were to be cut). The normal model was considered properly established if the main condition was fulfilled: at the end of the cutting cycle, the earlier normal state before cutting was established in all the elements of the structure.

The characteristic of these normal models, apart from the fact that they envisaged high growing stock before cutting, was that their increment was based on the state after cutting, but even the increment determined in this way was not completely designated for cutting, because certain amounts were kept as a reserve in case of unplanned cutting. As the concrete productive force of the normal model was made up of an average annual volume increment (arithmetic mean of the increment before and after cutting), as well as the stocks of the trees in the measurable part of the stand, it was clear that due to the cutting which was lower even than the increment of the growing stock after cutting, the growing stock per surface unit increased.

Klepac (1962) and Križanec (1963) believe that the success of permanent regeneration of these forests was hindered precisely by the surplus of growing stock.

The normal growing stock of these forests is represented with an arithmetic mean between the normal stock before and after cutting.

THE NEW SYSTEM OF SELECTION FOREST MANAGEMENT
NOVI SISTEM UREĐIVANJA PREBORNIH ŠUMA

In 1961, Klepac drew up the "New System of selection forest management". The new system was based on knowing the optimal (normal) growing stocks, that is, those amounts of the growing stock to be retained in a forest permanently. The size and structure of such growing stocks should be such (neither too high nor too low) as to enable permanent regeneration of a forest and yield the most favourable income (Klepac 1961).

The normal state of a selection forest is based on the basic tree series of different diameters, of which every year one tree reaches the maturity dimension, and on several sets of complementary series that compensate for the trees selected by natural or artificial selection.

Normal models are based on Susmel's correlations for fir, Colette's correlations for beech and Šurić's site classes.

Table 2. Susmel's and Collete's correlations (according to Klepac 1961)
Tablica 2. Prikaz Susmelovih i Coletteovih korelacija (prema Klepcu 1961)

	Fir – *Jela* (Susmel)	Beech – *Bukva* (Colette)
v	$\frac{(h_{dom})^2}{3}$	$\frac{(h_{dom})^2}{4.23}$
q	$\frac{4,3}{\sqrt[3]{h_{dom}}}$	$\frac{4,54}{\sqrt[3]{h_{dom}}}$
G	0,97 h_{dom}	0,73 h_{dom}
d_{max}	2,64 h_{dom}	2,33 h_{dom}

h_{dom} – mean height of dominant trees (m) *srednja visina dominantnih stabala* (m)
V – normal growing stock (m³/ha) *normalna drvna zaliha* (m³/ha)
q – coefficient of geometric progression of a normal tree series *koeficijent geometrijske progresije normalnoga niza stabala*
G – optimal basal area (m²/ha) *optimalna temeljnica* (m²/ha)
d_{max} – dimension of physical maturity (cm) *dimenzija fiziološke zrelosti* (cm)

Klepac constructs his normal models in the following way:

On the basis of dominant heights taken from Šurić's site classes, he calculates the elements listed above (V, q, G, d_{max}) and on the basis of the physical maturity dimension (d_{max}) and the coefficient of geometric progression (q) determines a standard tree series (expressed by Liocourt's curve). The number of the trees to be found in an individual diameter degree is obtained from a geometric progression ($q^n, q^{n-1}, q^{n-2}, ... q^2, q^1, q^0$), where q^0 represents the number of trees in the diameter class which contains the dimension of physiological maturity, and n - total number of diameter classes. He goes on to calculate the basal area for every diameter class and the total basal area of the normal series. Putting the optimal basal area (G) into the relationship with the total basal area of the normal tree series, he obtains the correction factor (f), with which he multiplies the number of trees of the normal series and obtains the optimal series of the tree number. Based on the optimal series of the tree number (that should always be in the forest), he calculates the basal area and the growing stock. This concludes the procedure of constructing the normal model with the physiological maturity dimension.

Klepac (1961) says that an artificially balanced curve of the tree number, if there are reasons for this, can be stopped earlier, and so he constructs normal models with the dimension of maturity for the fir of 60 cm, and for the beech of 50 cm. The sum of the basal areas of diameter classes above a certain maturity dimension is proportionally distributed to the remaining diameter classes. Based on these increased basal areas, he calculates the number of trees and the growing stock of every one degree.

The normal state before and after cutting is obtained by differentiating frequency curves of the tree number. Dividing the difference of the tree number of two adjacent diameter degrees with the transitional time of the lower degree, and multiplying it with the tariff, he obtains the annual volume increment. By adding or subtracting the five-year increment to the growing stock of any one degree (for the cutting cycle of 10 years), he obtains its growing stock before (M) or after cutting (m). On the basis of the growing stock before or after cutting, he calculates the number of trees in any one diameter degree and its basal area.

In 1963, Škopac uses Klepac's normal models to construct mixed normal models for the III site class for different species mixes, with physiological maturity. In this case, the species mix does not represent a percentage or a relative participation of an individual species, but shows which part of the pure normal model of an individual species is taken to construct mixed normal models. For example, to construct a mixed normal model of fir 0.8 : beech 0.2, 80 % of the pure fir normal model and 20% of the pure beech normal model are taken.

Klepac (1965) points out that the 10% of beech trees do not interfere with fir's growth, and therefore, normal models can also be constructed with the following ratios: 0.9:0.2; 0.8:0.3; 0.7: 0.4, etc.

Klepac emphasises that he was led to construct normal models because of differing opinions about the optimal state of Croatian selection forests. Due to unfamiliarity with some newer theories concerning the management of selection forests, the Croatian forests were not treated scientifically. He also points out that his normal models are of a temporary character, as in his future work he plans to study the normal models by forest types (according to Križanec 1987).

NORMAL MODELS BY EMTS
NORMALE PO EGT-OVIMA

Normal models by forest types were not constructed by Klepac, as had been his intention, but by the staff of the Forestry Institute in Jastrebarsko, headed by Cestar. They adapted the existing Klepac's normal models to forest types (Križanec 1987).

According to Cestar (1987) "The ecological-management type is the basic unit of typological classification." It represents a certain area of forests and forestland with similar ecological and management characteristics that determine the management method. A forest type is established on the basis of geological substrate, soil type and forest community, as well as silvicultural features, productive capacities and stand values of natural tree species. The best stand form, rotation, cutting maturity diameter, normal production and its value and the method of management are found for each type. A sub-type can be classified within an ecological-management type, which differs from the type in the method of management with regard to some ecological characteristics."

Cestar (1967) says that work on typological activities was based on the studied, described and clearly defined forest communities, to which further research within certain components of typological studies was added following detailed methods drawn by phytocoenologists, pedologists, micro-climatologists, silviculturalists, managers and economists.

According to Hren (1990), EMTs are descriptive forms which make classification, description and comparison of empirical data easier. Concrete data were only used in comparisons and idealising with the aim of obtaining the ideal type, which served as a guideline. Therefore, a type indicates potential possibilities of an area.

Hren (1990) goes on to say that a forest type is defined by an equal level of production, while other factors, such as, for example, regeneration, structure and similar, were hardly used.

Križanec (1987) compared Klepac's normal models and the normal models by EMTs: "Klepac's normal models are flexible and can be adapted to every given forest with regard to its condition at the time of management. Cestar's normal models are not of the same diapason.

They are applicable for a given forest type with a certain maturity dimension. Klepac's models can be adapted to every maturity dimension, ranging from technical to physiological, which is indispensable in a selection forest, because there, the thicker the healthy fir trees are, the better their increment."

RESEARCH TASKS AND GOAL
ZADACI I CILJ ISTRAŽIVANJA

Present the methods serving as a source of the models used in managing these forests;

Present and compare the models to be achieved in these forests;

Compare the present structure of some stands with their former structures and with the proposed models in order to establish their deviations;

Find out if the condition of the stands managed by various owners in the past differs from the condition today, after almost half a century of management by one owner and with the same methods; establish if any possible differences could be attributed to past management (management intensity);

Propose a model or several models to which these stands should aim in order to achieve the set management goal.

METHOD OF WORK
METODA RADA

Apart from presenting models of management with fir forests in Gorski Kotar, the development of several concrete stands will be monitored and compared with their models.

DATA COLLECTION
PRIKUPLJANJE PODATAKA

COLLECTING DATA ON MODELS
PRIKUPLJANJE PODATAKA O MODELIMA

The data on the models used in managing selection forests were taken from the literature written over a wide span, starting from the 80s of the 19th century to date.

The majority of the data on the normal models based on "The normal method before and after cutting", prescribed by the 1903 Instruction, were found in the works of Miletić (1950, 1951 and 1957), while the remaining data, as well as the normal models according to "The new system ..." and EMTs come from the original works of their authors (Kern 1898, 1916, Jovanovac 1925, Cestar et al. 1986).

COLLECTING DATA ON THE STANDS
PRIKUPLJANJE PODATAKA O SASTOJINAMA

In selecting the stands to be monitored over a period of time and compared with the proposed models, I was guided by two facts: a) in the past, some of them were managed by Ghyzy and some by Thurn-Taxis, b) there are numerous data on their structure in the past period. After consulting my colleagues from the Forest Management Department in the Forest Office Delnice, I have decided to focus on the stands from the management units of "Milanov Vrh" and "Crni Lug".

According to the 1990 management plan, the sub-compartments selected for research belong to the EMT I-C-10b, which is the best represented in both MU (in the MU "Milanov Vrh" with 73.8%, and in the MU "Crni Lug" with 37.2%). Table 3 contains a part of the database for this EMT in the MU "Milanov Vrh". The database was drawn in the Excel and was used to select the stands to be measured. Two stands were selected in each MU.

Table 3. A part of the EMT I-C-10b database used to select stands to be investigated in MU "Milanov Vrh"

Tablica 3. Dio baze podataka EGT-a I-C-10b na temelju koje su odabrane sastojine u kojima će se istraživati u GJ "Milanov vrh"

Com-partment *Odjel*	Sub-compartment *Odsjek*	Area (ha) *Površina (ha)*	Tree distribution *Raspored stabala*	Management class (by cover) *Uređajni razred (prema obrastu)*	Percentage of growing stock *Postotni udio drvne zalihe*					
					Fir *Jela*	Spruce *Smreka*	Beech *Bukva*	OTS *OTB*	Coniferes *Crnogorica*	Hardwoods *Bjelogorica*
1	a	13.90	Single-tree *Stablimični*	Below the norm *Ispod normale*	71	14	12	3	85	15
1	b	8.01	Cluster *Skupinasti*	Normal *Normalni*	10	67	21	2	77	23
1	c	49.01	Single-tree *Stablimični*	Normal *Normalni*	70	16	12	2	86	14
2	b	44.53	Single-tree *Stablimični*	Normal *Normalni*	75	21	4	0	96	4
...	...	...	...	...	...	...	...	...	...	...
60	a	44.50	Single-tree *Stablimični*	Below the norm *Ispod normale*	71	24	5	0	95	5
60	b	40.82	Single-tree *Stablimični*	Normal *Normalni*	70	22	8	0	92	8

The stands were selected according to the following criteria: compartment size over 10 ha; single-tree distribution; normal management class (cover). Of a total of 79 stands within the mentioned EMT, 30 satisfied these criteria. Additional criteria for the first stand required that the percentage share of the coniferous growing stock be ≥ 80%, and of the fir ≥ 70%, and for the second stand the percentage share of the hardwoods be ≥ 35% and of the fir ≥ 50%. The criteria for the first stand were met by five (1c, 2b, 9a, 9b, 16b), and for the second stand by three (13a, 18, 19a) stands. After analysing their past management plans (areas, boundaries and growing stock), I selected sub-compartment 2b for the first stand and 13a for the second stand.

Compartments 39c and 61b in the MU "Crni Lug" were selected in the same way.

For the selected stands, the data on frequency distributions of tree numbers and stocks by diameter degrees or classes were taken from the earlier management plans at my disposal. The stand parameters in these stands were measured during the summer and autumn of 1997.

I had intended to do the measurements in each of the selected stands on a sample plot sized 1 ha, but after making a round of the terrain, I noticed that the structure of the stand was heterogeneous. Therefore, I did the measurements in smaller plots in order to assess all the conditions in the stand.

Both my experience and the research by Sayn-Wittgenstein shows that a plot has an optimal size if the number of measurable trees (n) ranges from 6 - 16, depending on the dimensions of breast diameters (Pranjić 1977). This is why I chose a square plot sized 0.0578 ha and set up a total of 16 plots of 0.9248 ha in each stand. The plots were arranged as a systematic sample, and were marked with 17-m-long semi-diagonals.

Field work involved measuring breast diameters of the trees over the taxation limit (10 cm), measuring heights for the purpose of constructing a height curve, and taking increment cores for the purpose of determining the tree transition time for constructing normal models before felling. For each stand, about 90 heights were measured and as many increment cores taken.

DATA PROCESSING
OBRADA PODATAKA

PROCESSING THE DATA RELATED TO THE MODELS
OBRADA PODATAKA VEZANIH UZ MODELE

As the distribution in a part of the old normal models was expressed in diameter classes of different breadths (e.g. diameter class II; 25-34 cm; 25-37 cm; 27-40 cm, ...), I adjusted these normal models to decating diameter classes in order to present them graphically.

Adjustment was done under the assumption that the frequency curve of the tree number had the shape of Liocourt's hyperbolic curve.

For the purpose of comparison with the old normal models, I constructed (according to Klepac) pure normal models for the fir for the condition before cutting, with a cutting cycle of 10 years and the maturity dimension of 60, 65 and 70 cm and the Institute's normal model for the condition before cutting with a 10-year cutting cycle and the maturity dimension of 70 cm.

I used the New System to construct pure normal models for the II and II/III site class of fir and the II, III and III/IV site class of beech with the physiological maturity and maturity dimension of 70 cm for the fir and 50 cm for the beech, and mixed normal models of fir : beech = 60% : 40% (the II-II site class - for the purpose of comparison with the Institute's normal model EMT I-C-10b), and 70% : 40% and 60% : 50% (the II-III and the III-IV site class) of the tree number of pure normal models - models for the studied stands.

PROCESSING THE DATA OF THE SELECTED STANDS
OBRADA PODATAKA ODABRANIH SASTOJINA

The data obtained from measuring breast diameters enabled calculations of the structure by tree number (reduced to ha) per plots and compartments. By mathematical equalisation of the measured heights with Mihailo's function

$$h=b_0 \cdot e^{-b_1/d} + 1.30$$

h – tree height - *visina stabla*
d – breast diameter - *prsni promjer*
e – natural logarithm base - *baza prirodnoga logaritma*
b_0 – regression constant - *regresijska konstanta*
b_1 – regression coefficient - *regresijski koeficijent*

Fir height curves were obtained for every sub-compartment separately. The local tariffs were constructed on the basis of height curves and Špiranec's two-parameter tables of the growing stock for fir (timber) (Špiranec 1976). Based on the calculated structure by tree number and local tariff, I calculated the structure by growing stock (per ha) per plots and sub-compartments.

The analysis of the increment cores provided transition times of every sampled tree. The transition times of any one diameter class (its median, with weight) were equalised with the function $VP = b_0 + b_1/d + b_2/d^2$,

VP – transition time - *vrijeme prijelaza*
d – breast diameter - *prsni promjer*
b_0 – regression constant - *regresijska konstanta*
b_1, b_2 – regression coefficients - *regresijski koeficijenti*

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

THE RESULTS OF MODEL STUDY
REZULTATI ISTRAŽIVANJA O MODELIMA

The majority of the collected models related to pure normal models of both fir and beech for the condition before and after cutting. They were used for the construction of mixed normal models. In presenting the distribution of the number of trees per diameter classes in the old normal models I focused on pure fir normal models before cutting.

Kern's normal models. In my research I shall present two of Kern's normal models (pure fir - the state before cutting). The normal model for the former land community (f. l. c.) Hreljin from 1898 (1.) (the numbers in brackets relate to the ordinal number of normal model in Table 4). In the forest, Kern found a stand or its part containing full cover and regarded the measured basal area to be the normal basal area. He divided it with the number of diameter classes (5), so that each diameter class was represented by an equal basal area. The maturity dimension was 60 cm.

The normal model for the f. l. c. Crni Lug from 1916 (2.). There, Kern abandoned his thesis that individual diameter classes had equal basal areas, and said that the "sum total of basal areas will be the smallest in the lowest, and the biggest in the highest diameter class" (Kern 1916). The maturity dimension was not strictly defined, contrary to the number of trees above 51 cm in diameter.

Majnarić's normal models. A total of nine normal models, constructed in the period 1913-1941, were analysed. In the majority of the models: for f. l .c. Mrzla Vodica (vicinity of Risnjak) from 1913 (3), f. l. c. Ravna Gora (Velika Kapela - below Bjelolasica) from 1924 (4), f. l. c. Dol (vicinity of Fužine) from 1926 (5), f. l. c. Lokve from 1928 (6), f. l. c. Drivenik (vicinity of Lič above Fužine) from 1930 (7), f. l. c. Belgrad – MU Strilež-Ravno (below Viševica) from 1934 (8) and f. l. c. Fužine (new estate) from 1941 (11), Majnarić started from the fact (considered proven at the time) that the sum of basal areas of fir at full cover was about 52 m^2 (Miletić, 1957). More significant deviation of the basal area is expressed in the normal models for the f. l. c. Belgrad, MU Falšja Draga from 1934 (9) (41.47 m^2) and the f. l. c. Novi Zagon from 1938 (10) (40.40 m^2), because there were no "normal" stands of fir in these MUs. For the f. l. c. Fužine, the forest of Rogozno (the old estate), Majnarić constructed normal models for different species mixes that he found in the forest, and presented the data on the basal area and the growing stock summarily.

Jovanovac's normal models. Jovanovac based his normal models for the f. l. c. Benkovac (near Fužine) from 1912 (12) and f. l. c. Hreljin-Ružić Selo from 1914 (13) on the equality of the basal areas of individual diameter classes.

Tvrdony. In constructing a normal model for the f. l. c. Fužine (the old estate) from 1926 (14), he found that the basal area ranged widely from 31.32 - 77.70 m^2 per ha. He considered the basal area of 62.64 m^2 to be the ideal basal area before cutting, and constructed a normal model in which the sum of the basal areas was 63.81 m^2.

Matizović also based his normal models for the former estate Severin na Kupi from 1936 (15) and former estate Sušica na Mostu from 1929 (16) on the total basal area per ha, while *Žagar* in the normal model for the f. l. c. Crikvenica from 1935 (17) adjusted the condition in the forest to a full cover and corrected the irregularities graphically.

Šimić constructed his normal models for the management class (MC) Bijela Kosa-Bazgovac (23) and MC Makovnik-Crni Potok (24), both from 1911, for the former Ogulin property commune (vicinity of Plaško) in mixed stands of fir and beech with the 1 : 1 and 2 : 1 ratios (fir, beech). He also maintained that a pure fir stand before cutting should have about 52.2 m^2, and that of beech 34.8 m^2.

The basic postulates of Miklavžić's normal models for the f. l. c. Zlobin from 1930 (18-22) are not known.

Summary data on these normal models are given in Table 4 and the distribution of tree numbers by diameter classes for the majority of them are given in Figure 3 (3.1. - 3.4.).

The EMT I-C-10b model consists of 60% of the number of trees of pure fir and 40% of the

Table 4. Summary data on the models based on the normal method before and after cutting

Tablica 4. Sumarni podaci o modelima nastalim na temelju metode normala prije i poslije sječe

Nr. *Br.*	Author *Autor*	Formulated in *Nastala*	Site class *Bonitet*	Before cutting - *Prije sječe*			Rotation *Ophodnjica*	After cutting - *Poslije sječe*			Increament * *Prirast**	Increment ** *Prirast***	Felling *Etat*	Intensity of cutting *Intenzitet sječe*
				N	G	V		N	G	V				
		Year – *god.*		pcs/ha	m²/ha	m³/ha	Years – *god.*	pcs/ha	m²/ha	m³/ha	m³/ha	m³/ha	m³/ha	%
1.	Kern	1898.	I	1023	53	574	20		42	441			6.65	1.16
2.		1916.	I	709	53	535.88	25	610	36.58	345.01			7.63	1.42
3.	Majnarić	1913.	srednji	605	52.53	551.86	25	551	36.66	347.87	10.42	8.41	8.16	1.48
4.		1924.		644	53.07	559.96	25	508	35.50	350.43	10.78	8.70	8.38	1.50
5.		1926.	srednji	575	55.94	625.10	25	481	38.39	420.25	10.14	8.82	8.19	1.31
6.		1928.		664	57.49	586.66	25	578	40.42	386.79	10.21	8.38	8.00	1.36
7.		1930.		549	48.81	492.92	20	402	30.17	286.42	9.00	6.87	10.32	2.09
8.		1934.		791	52.48	544.25	25	659	36.11	353.87	9.83	7.92	7.62	1.40
9.		1934.		670	41.75	289.06	12	584	32.51	225.50	6.11	5.41	5.30	1.83
10.		1938.		462	40.40	392.56	30	425	29.23	261.01	5.09	4.35	4.38	1.12
11.		1941.		j:b = 0.9:0.1	53.98	688.36	20			516.27			10.22	
12.	Jovanovac	1912.		847	50.46	594.34	20	680	34.80	398.35	12.34	10.38	9.80	1.65
13.		1914.		990	59.16	652.18	20	845	43.50	460.12	11.15	9.48	9.60	1.47
14.	Tvrdony	1926.		649	63.81	729.06	20		40.02				11.80	
15.	Matizović	1936.		637	48.99	542.10	20	528	26.64	283.07	13.41	9.64	12.95	
16.		1929.		785	46.31	490.35	20	573	29.18	269.94	12.65	9.82	11.02	2.25
17.	Žagar	1935.	III	689	49.24	564.44	20	513	31.17	326.59			11.89	2.11
18.	Miklavžič	1930.	II	699	46.98	536.76	20	644	33.72	374.17	8.83	7.46	8.13	1.51
19.		1930.	III	699	46.98	426.93	20	644	33.72	284.89	7.43	6.26	6.60	1.55
20.		1930.	IV	699	46.98	305.89	20	644	33.72	201.77	7.43	6.26	5.20	1.70
21.		1930.	II	760	52.15	598.19	20	697	37.27	415.28	9.82	8.28	9.14	1.53
22.		1930.	III	Vrijedi normala od GJ A za isti bonitet										
23.	Šimić	1911.		901 j:b=2:1	46.37	429.50	30	623	28.40	252.29			5.91	1.38
24.		1911.		707 j:b=1:1	42.60	405.35	30	512	26.24	230.72			5.82	1.44

*Arithmetic means of stock increment before and after cutting; ** Stock increment after cutting

* *Aritmetička sredina prirasta zalihe prije i poslije sječe;* ** *Prirast zalihe poslije sječe*

number of trees of pure beech model (both for the II site class), with the maturity dimension of 70 cm for the fir, and of 50 cm for the beech. I constructed Klepac's normal model under the same conditions. The dominant trees, whose heights are used to construct Klepac's normal models, are defined differently by different authors, which leads to a decrease in the heights and the growing stocks of the constructed normal models (Božić & Čavlović 2001). For this reason, in constructing the normal models, I used the dominant heights that Klepac also used.

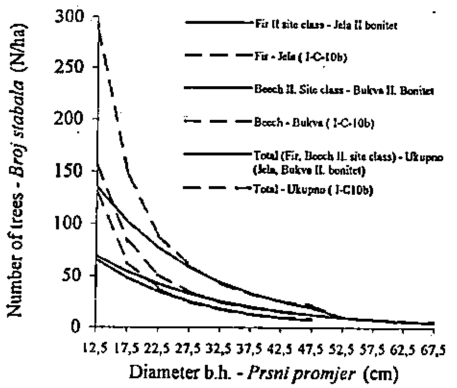


Figure 1. The position of the Institute's normal model (I-C-10b) towards Klepac's normal model

Slika 1. Položaj institutske normale prema Klepčevoj normali

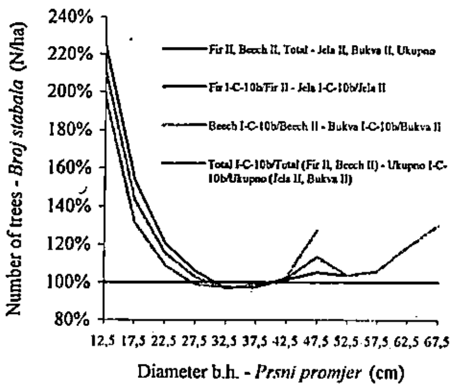


Figure 2. The relationship of the Institute's normal model (I-C-10b) and Klepac's normal model

Slika 2. Odnos institutske normale prema Klepčevoj normali

Since „old" normal models showed the condition of stands before (and after) cutting, in order to compare them with the models used more recently I used the „New System ..." to construct Klepac's and the Institute's normal model for pure fir, the condition before cutting, with a 10-year cutting cycle. The Institute's normal model was constructed with the maturity dimension of 70 cm, and Klepac's model with the maturity dimensions of 70, 65 and 60 cm.

The normal models in Figures 3.1 - 3.4 were grouped by the indicated or assumed maturity dimensions, which also served to construct Klepac's normal model. In Figure 3.1, a maturity dimension of 60 cm was indicated for the normal model of the f. l. c. Hreljin, while maturity dimensions for other normal models were not defined. As the breadth of earlier diameter classes was 10 cm in decatic division, I assumed that the breadth of the final diameter class was 10 cm. Therefore, the maturity dimension was 60 cm. The normal models shown in Figures 3.2 - 3.4 were also grouped, that is, their maturity dimensions were defined in the same way.

Figure 3.1. - *Slika 3.1.*

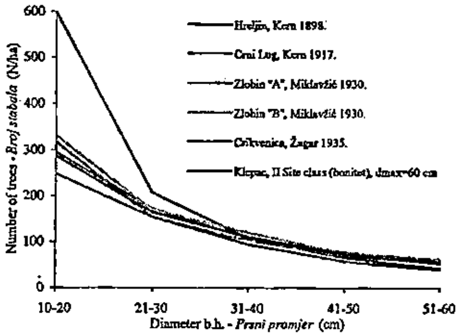


Figure 4.1. - *Slika 4.1.*

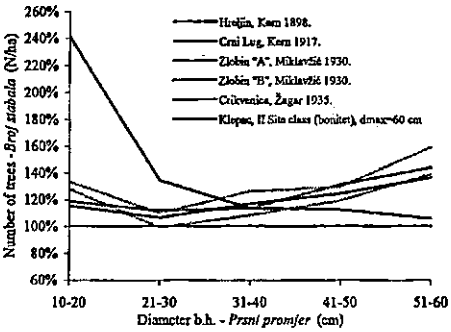


Figure 3.2. - *Slika 3.2.*

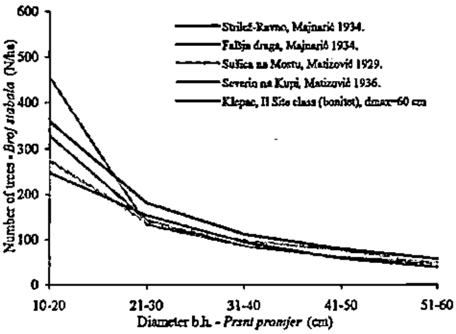


Figure 4.2. - *Slika 4.2.*

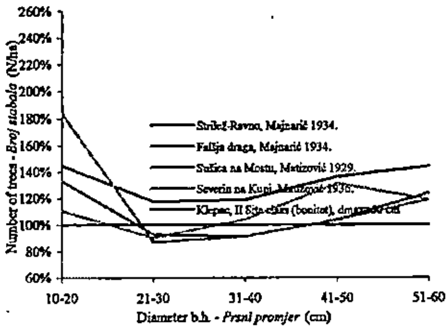


Figure 3.3. - *Slika 3.3.*

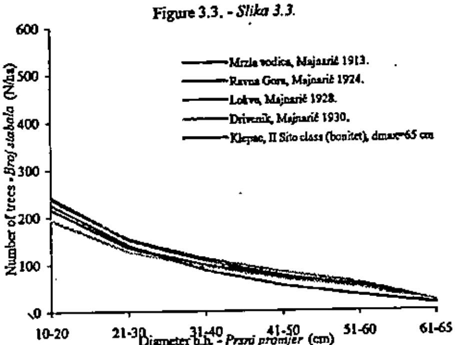
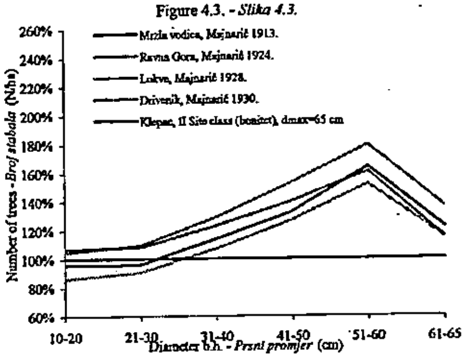
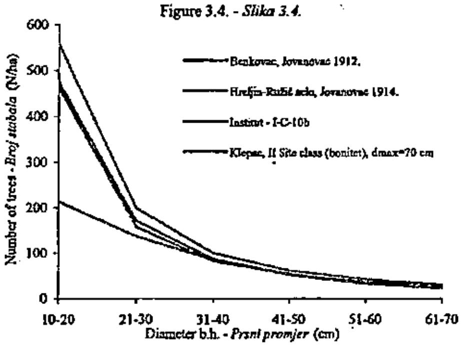


Figure 4.3. - *Slika 4.3.*





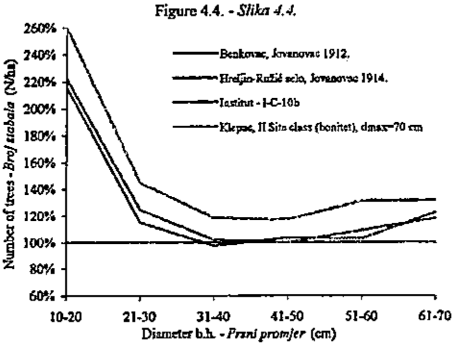


Figure 3. (3.1 - 3.4) The position of some old normal models and the Institute's model towards Klepac's model (pure fir before cutting)

Slika 3. (3.1.-3.4.) Položaj nekih starih normala te institutske normale prema Klepčevoj normali (čista jela prije sječe)

Figure 4. (4.1 - 4.4) The relation of some old normal models and the Institute's model towards Klepac's normal model (pure fir before cutting)

Slika 4. (4.1.-4.4.) Odnos nekih starih normala te institutske normale prema Klepčevoj normali (čista jela prije sječe)

THE RESULTS OF RESEARCH IN STANDS
REZULTATI ISTRAŽIVANJA U SASTOJINAMA

Under earlier management plans, the stands within the EMT I-C-10b belonged to different site classes. The selected stands were therefore compared with the normal models of the concrete site classes to which these stands belong.

Based on the measured heights, I constructed a height curve for each stand. By inserting stand height curves of the fir into the boundaries of Šurić's (Pranjić) site classes (Božić 2000), I defined (based on the dominant part of the stand) the site class to which the fir in the given stand belongs.

In the stands 39b and 61b, the fir belongs to the II, and in the stands 2b and 13 a, it belongs to the II/III site class. As the heights of the beech were not measured, the site class of beech was determined on the basis of the data from old management plans, according to which the site class of beech was worse by one site class than that of fir. Thus, the beech in the stands 39c and 61b was placed into the III, and in the stands 2b and 13a into the III/IV site class.

Table 5. The structure of a stand per hectare - sub-compartment 2b

Tablica 5. Struktura sastojine po hektaru - odsjek 2b

$d_{1.30}$	Jela - Fir			Smreka - Spruce			Bukva - Beech			Ostalo - Other			Ukupno - Total		
	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
12.5	37.8	0.46	1.93	4.3	0.05	0.22	44.3	0.54	1.77				86.5	1.06	3.92
17.5	46.5	1.12	7.25	13.0	0.31	2.02	32.4	0.78	3.57				91.9	2.21	12.85
22.5	32.4	1.29	10.80	7.6	0.30	2.52	14.1	0.56	3.09	1.1	0.04	0.24	55.1	2.19	16.65
27.5	22.7	1.35	13.24	10.8	0.64	6.30	3.2	0.19	1.23	1.1	0.06	0.41	37.8	2.25	21.19
32.5	42.2	3.50	38.25	7.6	0.63	6.87	4.3	0.36	2.55				54.1	4.48	47.67
37.5	36.8	4.06	48.05	7.6	0.84	9.89	1.1	0.12	0.93				45.4	5.01	58.87
42.5	21.6	3.07	38.21	5.4	0.77	9.55	1.1	0.15	1.30				28.1	3.99	49.06
47.5	23.8	4.21	54.71	3.2	0.57	7.46							27.0	4.79	62.18
52.5	14.1	3.04	40.71	9.7	2.11	28.18							23.8	5.15	68.89
57.5	7.6	1.96	26.90	7.6	1.96	26.90							15.1	3.93	53.80
62.5	4.3	1.33	18.51	2.2	0.66	9.25							6.5	1.99	27.76
67.5	2.2	0.77	10.92	1.1	0.39	5.46							3.2	1.16	16.38
72.5	2.2	0.89	12.72										2.2	0.89	12.72
77.5	1.1	0.51	7.32										1.1	0.51	7.32
82.5															
87.5															
92.5															
97.5															
Total	295.2	27.56	329.53	80.0	9.23	114.64	100.6	2.71	14.45	2.2	0.11	0.65	477.9	39.61	459.26

Table 6. The structure of a stand per hectare - sub-compartment 13a

Tablica 6. Struktura sastojine po hektaru - odsjek 13a

$d_{1.30}$	Jela - Fir			Smreka - Spruce			Bukva - Beech			Ostalo - Other			Ukupno - Total		
	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
12.5	96.2	1.18	4.72	5.4	0.07	0.26	45.4	0.56	3.18	1.1	0.01	0.08	148.1	1.82	8.24
17.5	44.3	1.07	6.78	10.8	0.26	1.65	28.1	0.68	4.78				83.3	2.00	13.22
22.5	45.4	1.80	14.94	8.7	0.34	2.85	17.3	0.69	5.71				71.4	2.84	23.50
27.5	33.5	1.99	19.31	2.2	0.13	1.25	15.1	0.90	8.48	2.2	0.13	1.21	53.0	3.15	30.24
32.5	23.8	1.97	21.46	4.3	0.36	3.90	20.5	1.70	17.67	2.2	0.18	1.86	50.8	4.21	44.89
37.5	18.4	2.03	23.92	1.1	0.12	1.41	15.1	1.67	18.92	2.2	0.24	2.70	36.8	4.06	46.95
42.5	28.1	3.99	49.68	2.2	0.31	3.82	17.3	2.45	29.93	1.1	0.15	1.87	48.7	6.90	85.30
47.5	19.5	3.45	45.12	4.3	0.77	10.03	13.0	2.30	29.84	1.1	0.19	2.49	37.8	6.70	87.47
52.5	4.3	0.94	12.57	1.1	0.23	3.14	3.2	0.70	9.63				8.7	1.87	25.35
57.5	7.6	1.96	27.00	1.1	0.28	3.86	0.0	0.00	0.00	1.1	0.28	4.05	9.7	2.53	34.91
62.5	7.6	2.32	32.51				1.1	0.33	5.02				8.7	2.65	37.53
67.5															
72.5				1.1	0.45	6.40							1.1	0.45	6.40
77.5															
82.5															
87.5															
92.5															
97.5															
Total	328.7	22.70	258.00	42.2	3.31	38.57	176.3	11.98	133.16	10.8	1.19	14.26	558.0	39.17	444.00

Table 7. The structure of a stand per hectare - sub-compartment 39c

Tablica 7. Struktura sastojine po hektaru - odsjek 39c

$d_{1,30}$	Jela - Fir			Smreka - Spruce			Bukva - Beech			Ostalo - Other			Ukupno - Total		
	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
12.5	18.5	0.23	0.98	1.2	0.02	0.07	32.1	0.39	1.93	1.2	0.02	0.07	53.1	0.65	3.05
17.5	19.8	0.48	3.20	1.2	0.03	0.20	21.0	0.51	3.36	1.2	0.03	0.20	43.3	1.04	6.96
22.5	16.1	0.64	5.56				11.1	0.44	3.45	2.5	0.10	0.77	29.7	1.18	9.77
27.5	12.4	0.73	7.48	2.5	0.15	1.50	13.6	0.81	7.20				28.4	1.69	16.18
32.5	12.4	1.02	11.64	2.5	0.20	2.33	9.9	0.82	8.11	1.2	0.10	1.01	26.0	2.15	23.09
37.5	7.4	0.82	10.03				11.1	1.23	13.24	1.2	0.14	1.47	19.8	2.18	24.74
42.5	12.4	1.75	22.74				12.4	1.75	20.27	1.2	0.18	2.03	26.0	3.68	45.03
47.5	7.4	1.31	17.71	1.2	0.22	2.95	9.9	1.75	21.55	1.2	0.22	2.69	19.8	3.50	44.91
52.5	8.7	1.87	26.10				4.9	1.07	13.99	1.2	0.27	3.50	14.8	3.21	43.59
57.5	4.9	1.28	18.28	3.7	0.96	13.71	1.2	0.32	4.40				9.9	2.57	36.40
62.5	8.7	2.65	38.49										8.7	2.65	38.49
67.5	1.2	0.44	6.50										1.2	0.44	6.50
72.5	2.5	1.02	15.09	2.5	1.02	15.09							4.9	2.04	30.19
77.5	6.2	2.91	43.42				1.2	0.58	9.42				7.4	3.50	52.84
82.5	1.2	0.66	9.88										1.2	0.66	9.88
87.5	3.7	2.23	33.77										3.7	2.23	33.77
92.5	1.2	0.83	12.70										1.2	0.83	12.70
97.5	1.2	0.92	14.21										1.2	0.92	14.21
Total	145.8	21.81	297.79	14.8	2.60	35.85	128.5	9.67	106.91	11.1	1.04	11.74	300.3	35.12	452.29

Table 8. The structure of a stand per hectare - sub-compartment 61b

Tablica 8. Struktura sastojine po hektaru - odsjek 61b

$d_{1,30}$	Jela - Fir			Bukva - Beech			Ostalo - Other			Ukupno - Total		
	N	G	V	N	G	V	N	G	V	N	G	V
12.5	9.7	0.12	0.48	43.3	0.53	3.46				53.0	0.65	3.94
17.5	11.9	0.29	1.86	35.7	0.86	7.14	1.1	0.03	0.22	48.7	1.17	9.21
22.5	5.4	0.21	1.82	29.2	1.16	11.09	3.2	0.13	1.23	37.8	1.50	14.15
27.5	1.1	0.06	0.65	21.6	1.28	14.06	6.5	0.39	4.22	29.2	1.73	18.92
32.5	4.3	0.36	4.07	23.8	1.97	23.79	9.7	0.81	9.73	37.8	3.14	37.60
37.5	3.2	0.36	4.41	18.4	2.03	26.47				21.6	2.39	30.88
42.5	8.7	1.23	16.04	11.9	1.69	23.67	2.2	0.31	4.30	22.7	3.22	44.01
47.5	11.9	2.11	28.84	7.6	1.34	20.06	2.2	0.38	5.73	21.6	3.83	54.63
52.5	5.4	1.17	16.55	1.1	0.23	3.70				6.5	1.40	20.25
57.5	8.7	2.25	32.68				1.1	0.28	4.66	9.7	2.53	37.34
62.5	14.1	4.31	64.03							14.1	4.31	64.03
67.5	4.3	1.55	23.28							4.3	1.55	23.28
72.5	8.7	3.57	54.44							8.7	3.57	54.44
77.5	4.3	2.04	31.32							4.3	2.04	31.32
82.5	2.2	1.16	17.89							2.2	1.16	17.89
87.5	1.1	0.65	10.18							1.1	0.65	10.18
92.5												
97.5	1.1	0.81	12.92							1.1	0.81	12.92
Total	106.0	22.23	321.45	192.5	11.10	133.43	26.0	2.32	30.09	324.4	35.64	484.98

The normal model to be achieved through management can be specified by the distribution of the tree number, basal area and growing stock (volume). The number of trees in a given diameter class, obtained from direct measurements in the forest, represents the concrete value. With a constant number of trees within a given diameter class, the basal area is always the same. However, the growing stock, whether specified by the model, or calculated in a concrete stand, is not the same under a constant number of trees in diameter classes, but depends on the applied tariff.

Different tariffs have been used to calculate the growing stock in the past fifty years. The stocks calculated with the tariffs used so far (based on the measurement of 1997) show considerable deviations (Božić 2000). For this reason, in my further work I only observed trends in the distribution of tree numbers.

Fir stands are managed with the aim of achieving the most favourable species mix ranging from 70:30 to 80:20 % (fir : beech). For the sub-compartments under research I constructed Klepac's mixed normal models (60:50 and 70:40% of the tree number of pure models), which satisfy the mentioned species mixes per growing stock. I incorporated these normal models in the distributions of tree numbers and selected the one that corresponded to the concrete data with regard to the position (Figure 5 - 16).

Figures 5 – 16 Shifts in the distribution of tree numbers in the past period and their position according to the proposed model constructed with the species mix per growing stock: fir 80%: beech 20% (N_{fir} 70%: N_{beech} 40%), and fir 70%: beech 30% (N_{fir} 60%: N_{beech} 50%), with the physiological maturity dimension (*PM*) and maturity dimension (*MD*) of 70 cm for the fir and 50 cm for the beech.

*Slike 5 – 16. Pomaci distribucije broja stabala protekom vremena te njihov položaj prema predloženomu modelu načinjenomu uz omjere smjese po drvnoj zalisi: jela 80 % : bukva 20 % (N_{fir} 70 % : N_{beech} 40 %) te jela 70 % : bukva 30 % (N_{fir} 60 % : N_{beech} 50%), uz fiziološku dimenziju zrelosti (*PM*) te dimenziju zrelosti (*MD*) od 70 cm za jelu te 50 cm za bukvu.*

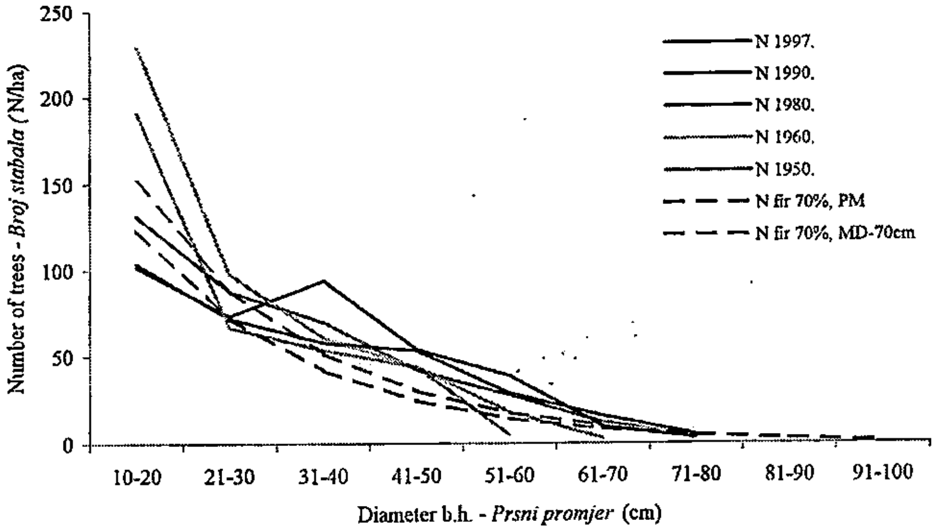


Figure 5. Sub-compartment 2b - fir II/III site class
Slika 5. Odsjek 2b - jela II/III bonitet

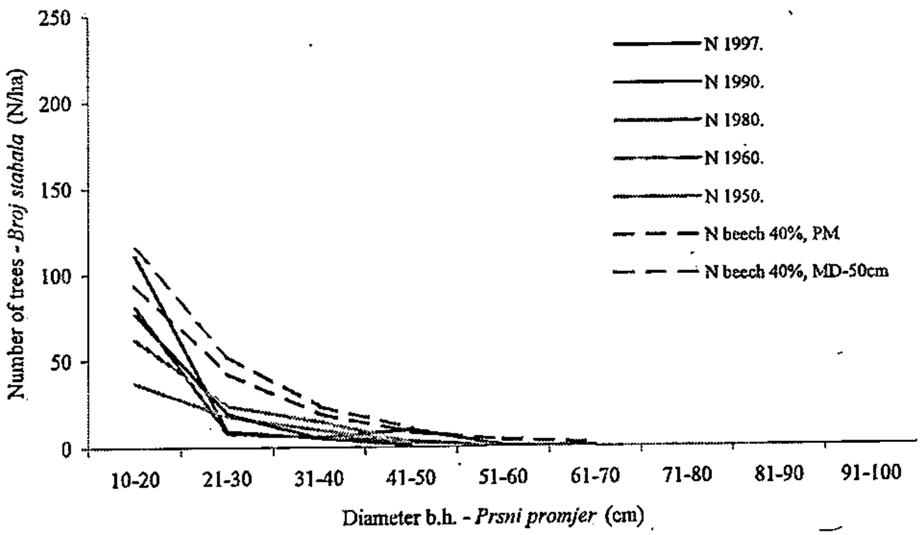


Figure 6. Sub-compartment 2b - beech III/IV site class
Slika 6. Odsjek 2b - bukva III/IV bonitet

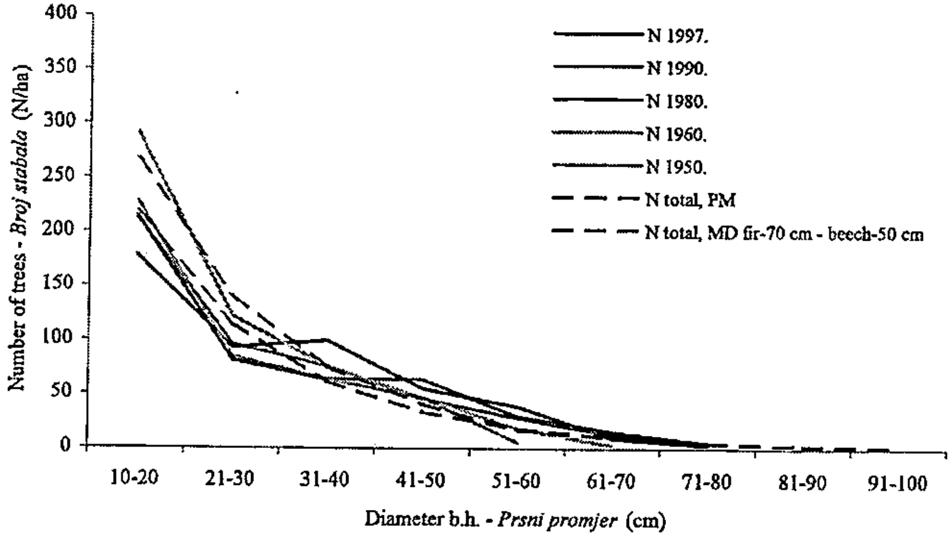


Figure 7. Sub-compartment 2b – total

Slika 7. Odsjek 2b – ukupno

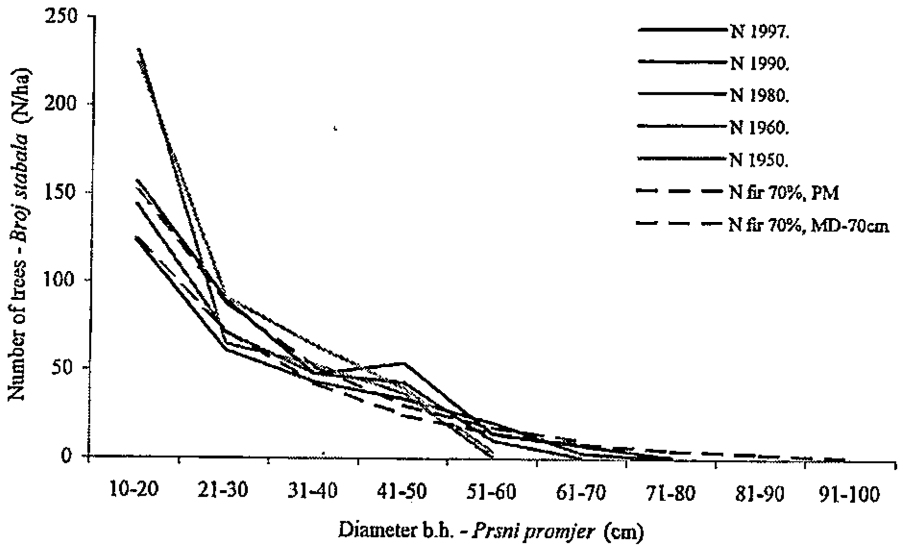


Figure 8. Sub-compartment 13a - fir II/III site class

Slika 8. Odsjek 13a - jela II/III bonitet

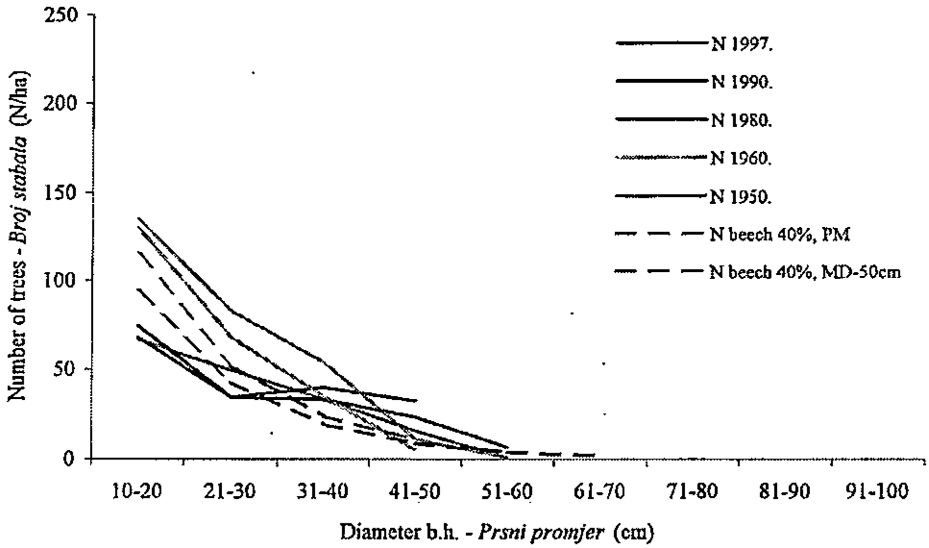


Figure 9. Sub-compartment 13a - beech III/IV site class

Slika 9. Odsjek 13a - bukva III/IV bonitet

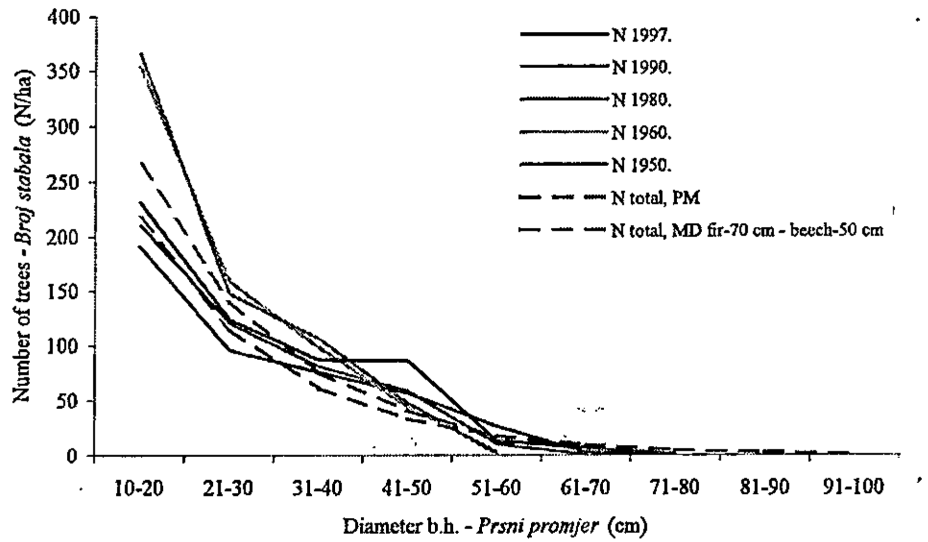


Figure 10.Sub-compartment 13a – total

Slika 10. Odsjek 13a – ukupno

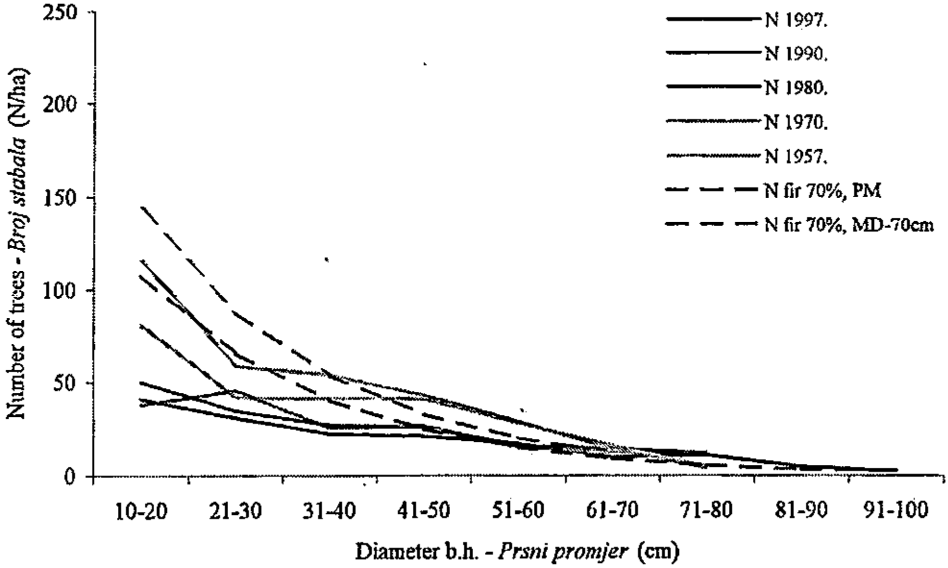


Figure 11. Sub-compartment 39c - fir II site class

Slika 11. Odsjek 39c - jela II bonitet

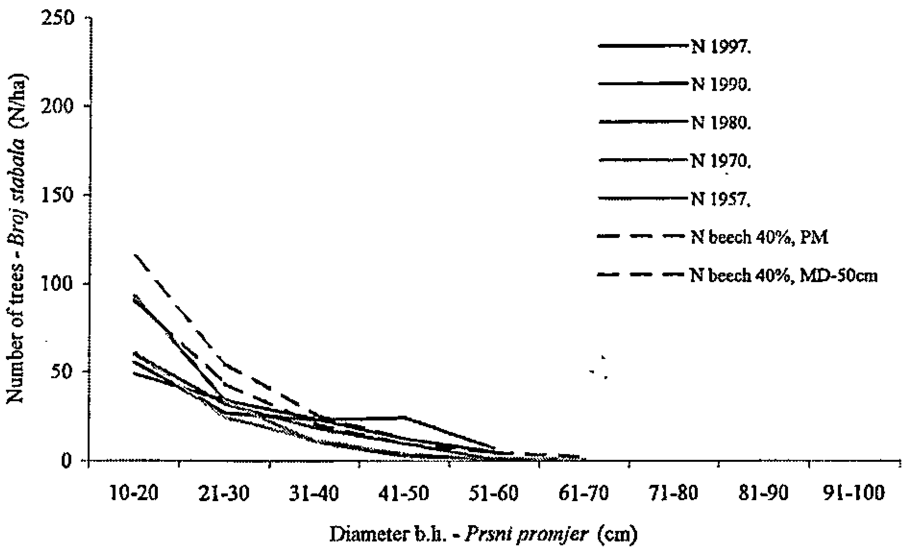


Figure 12. Sub-compartment 39c - beech III site class

Slika 12. Odsjek 39c - bukva III bonitet

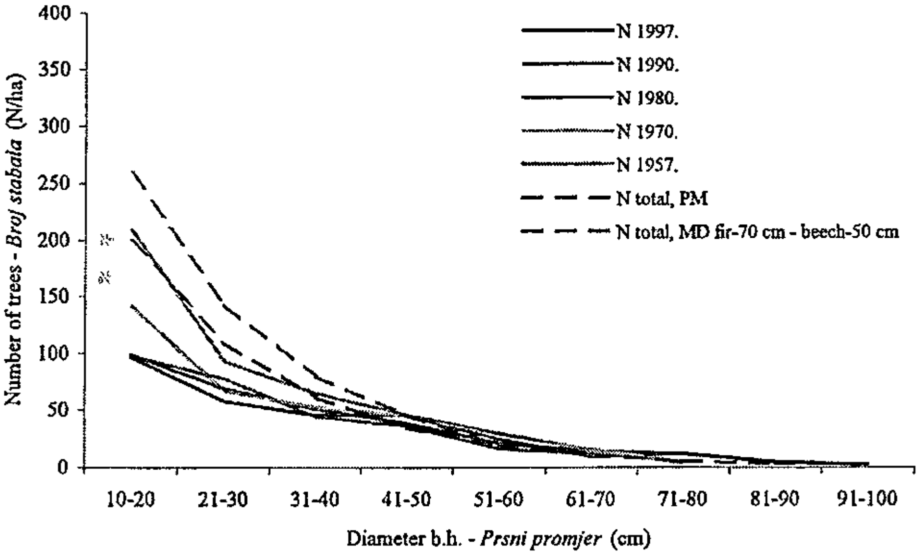


Figure 13. Sub-compartment 39c – total

Slika 13. Odsjek 39c – ukupno

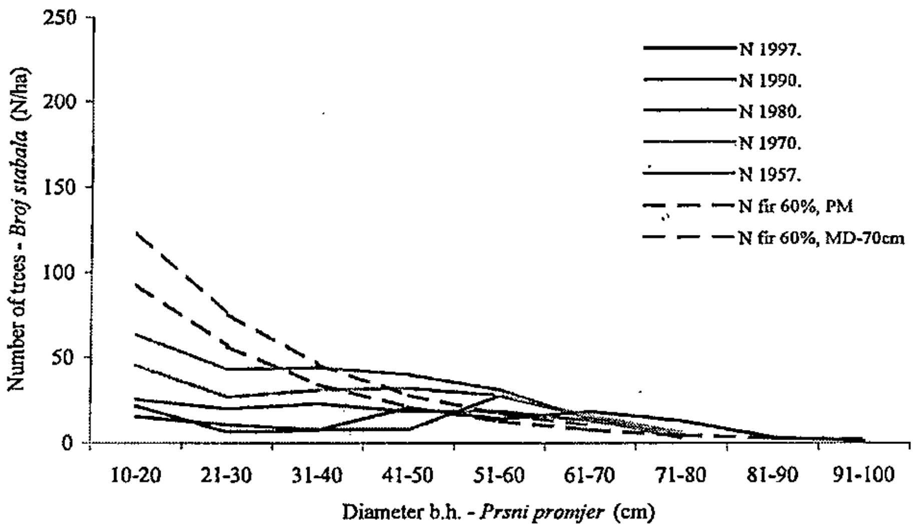


Figure 14. Sub-compartment 61b - fir II site class

Slika 14. Odsjek 61b - jela II bonitet

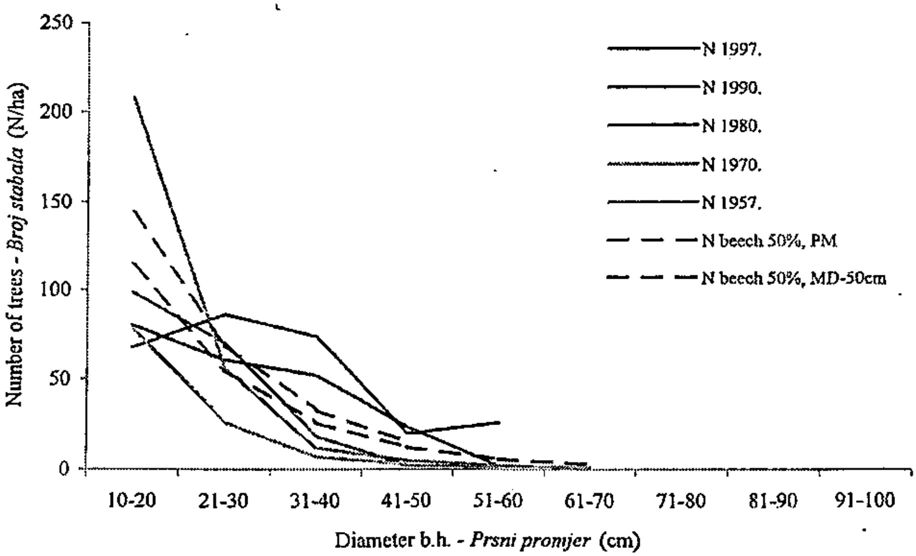


Figure 15. Sub-compartment 61b - beech III site class
Slika 15. Odsjek 61b - bukva III bonitet

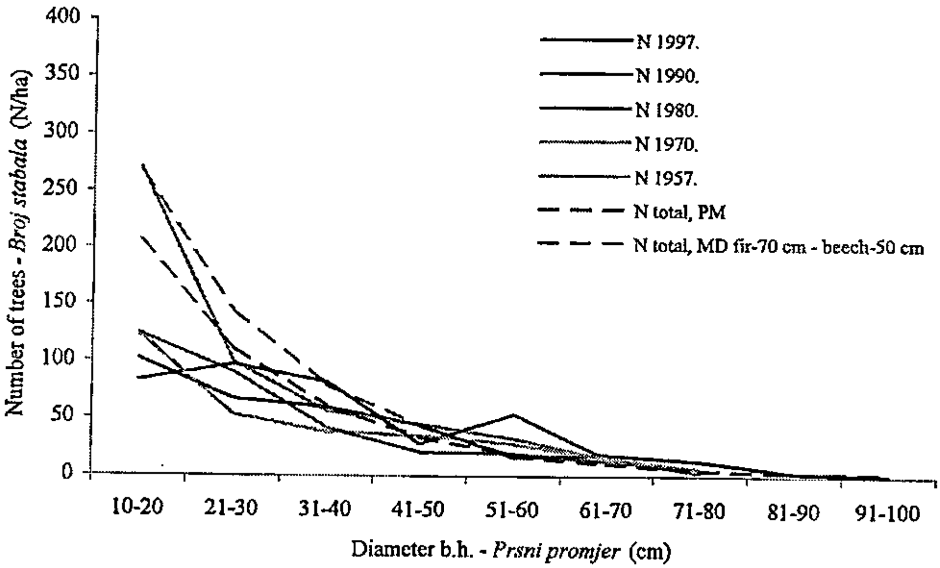


Figure 16. Sub-compartment 61b - total
Slika 16. Odsjek 61b - ukupno

DISCUSSION
RASPRAVA

DISCUSSING THE MODELS
RASPRAVA O MODELIMA

Kern's normal model for the land community (l.c.) Hreljin deviates considerably from Klepac's normal model. The deviation is the biggest in diameter class I, which contains 599 trees in Kern's normal model and 248 trees (+ 141%) in Klepac's model. In higher diameter classes the deviations decrease to + 6% in the last diameter class. The reason for such a large number of trees in lower diameter classes is the condition which was used for the construction of the model (the equality of basal areas of all diameter classes). Kern's normal model for the l.c Crni Lug is characterised by a slightly lower growing stock with a much smaller number of trees. In its construction, Kern abandoned the equality of basal areas of all diameter classes. More significant deviations from Klepac's normal models occur in the IV and V diameter class (31.23% and 44.05%).

Compared to Klepac's normal model, Majnarić's normal models are characterised by an excessive number of thick trees. This is most prominent in diameter class V, in which the number of trees is higher by 36-79% in relation to Klepac's models. In lower diameter classes deviations are less significant, and with some models the tree number curves in lower diameter classes are almost parallel to Klepac's normal model.

Miklavžić's and Žagar's normal models are similar to Kern's model for the l.c. Crni Lug.

Jovanovac's normal model was constructed under the same assumptions as Kern's model for the l.c. Hreljin (the equality of basal areas in given diameter classes). Therefore, their position and deviations in relation to Klepac's model are understandable. The smallest deviation in comparison with Klepac's model occurs in the number of medium thick trees, while it is almost equal in the normal model for the l.c. Benkovac.

With reference to normal models by EMT, Bertović *et al* (1974) say that they were constructed with the use of Klepac's models for beech and fir. What is interesting here, and can be seen in Figures 3.4 and 4.4, is that the Institute's normal model for EMT I-C-10b (recalculated for pure fir before cutting) overlaps almost completely with Jovanovac's normal model for the l.c. Benkovac.

In most of these models the growing stock exceeds 500 m^3/ha (up to 730 m^3/ha), which is understandable, since they contain a larger number of trees from higher diameter classes.

Another characteristic of the majority of these normal models is their long cutting cycle (20-30 years), with a low annual and high periodical cutting intensity. In very few cases does the annual cutting intensity exceed 2%, while the periodical one, for the length of the cutting cycle, usually amounts to about 35%, and sometimes reaches as much as 43.2%. According to the valid Forest Management Regulation, the cutting intensity in selection forests cannot exceed 25% (Anon. 1994); therefore, with regard to the silvicultural-ecological features of the species making up these forests, such high periodical intensities are beyond any comment.

In the majority of the cases the prescribed annual yield is slightly lower than the expected increment of the growing stock after cutting. The concrete stand increment is the arithmetic means between the growing stock increment before and the growing stock increment after cutting. The prescribed annual yield is considerably lower than the increment calculated in this way, which results in large quantities of growing stock in these forests.

Old normal models are characterised by the fact that they reflected the real state in the forest: thus, they testify to the appearance and condition of these forests at the time of constructing the models.

Figure 1 shows the position of the Institute's normal model for the EMT I-C-10b in relation to Klepac's normal model for the same site class, the species mix and the maturity dimension. In order to emphasise the growing stock, especially in the higher diameter classes, their mutual relationship is given in Figure 2. In both figures, the number of trees in lower diameter classes is considerably higher in the Institute's normal model. In the diameter class of 12.5 cm, the difference is the biggest in places where the number of trees in the Institute's normal model is higher by about 100 to 120% in relation to the same diameter class in Klepac's normal model. This difference decreases as the breast diameter increases. In diameter classes from 27.5 to 42.5 cm, the number of trees in both normal models is almost equal for all species. In diameter classes of 47.5 cm and higher, the Institute's normal model again shows higher values than Klepac's, which is shown in Figure 2.

The original model of the EMT-I-C-10b, with the species mix 60:40% of the pure number of firs and beeches shows the same deviation from the equivalent Klepac's model as the pure model before cutting. The deviation of fir is slightly higher than that of beech.

There is a single normal model for an EMT. It was constructed for a given site class (I-C-10b - site class II of fir and site class II of beech), while the stands classified into the type belonged to different site classes in the old management plans. The stands classified in the EMT I-C-10b were in the wide range of site classes, the fir from I/II to IV, and the beech from II to V.

STAND ANALYSIS
RASPRAVA O SASTOJINAMA

Sub-compartment 2b. In 1950, the distribution by the number of fir trees ends in the diameter class of 51-60 cm and has the shape of a falling distribution, where the slope of the falling line is not constant. The 1960 distribution retains the distribution trend of 1950, but is slightly higher and ends in the diameter class of 61-70 cm. Figure 5 shows that in the measurements of 1980-1997, the number of thin trees (10-30 cm) constantly decreases, while the number of medium thick (31-50 cm) and thick trees (51 > cm) increases. In this period, the distribution ends with the diameter class of 71-80 cm.

In relation to Klepac's normal model, the distribution of 1950 could be considered, with some slight corrections, as an achieved managed model. The 1960-1997 distributions move further away from Klepac's model, and there is a shortage of thin trees and a distinct surplus of medium thick and thick trees.

The stand contains 444.17 m³/ha of the growing stock of fir and spruce, which is almost 70% more than the stock planned in Klepac's model (70:40% with the maturity dimension of

70 cm).

In the period 1950-1990, there is an increase in the number of beech trees in lower diameter classes, while the number of medium thick and thick trees oscillates.

In relation to the normal model, there is a shortage of trees in all diameter classes, which is understandable since the real species mix in the stand is 97%:3% in favour of conifers, and not 80%:20%, as planned in the model. Had the mixed normal model been based on the real species mix, the deficit of thinner fir trees would be even more distinct, while the distribution curve of medium thick and thick trees would be closer to the model. The distribution curve of beech trees by diameter classes would be closer to the model in its entire course. The growing stock of beech is by 79% lower than the stock planned in the model.

The frequency distribution curve of the total number of trees in the stand of 1960 is higher than the curve of 1950 in its entire length. Later, the number of thin trees decreases, while the number of medium thick and thick trees increases. The distribution in 1960 is, as far as the total number of trees is concerned, the closest to the proposed model. Today, this stand has a deficit of thin and a surplus of medium thick and thick trees. The total growing stock exceeds the model by 37%.

A stronger cutting intensity and adequate consignation (of over-represented diameter degrees, classes) should stop the falling trend of thin trees and the rising trend of medium thick and thick trees; otherwise, the selection structure will be disturbed.

Sub-compartment 13a. In 1950 and 1960, the distribution of breast diameters of fir ends in the diameter class of 51-60 cm and has a falling trend, where the slope of the falling line is not constant. The 1960 curve shows slightly higher values in almost the whole length. After that, according to the measurements in 1980 and 1990, there is a considerable drop in the number of trees in the class of thin and medium thick trees and a rise in the class of thick trees. The distribution ends with the diameter class of 61-70 cm and of 71-80 cm. The last measurement shows an increase in the number of trees in all diameter classes.

The situation in the last measurement (1997) follows the proposed model most adequately. The 41-50-cm diameter class shows a more significant deviation from the model, where the number of trees in the concrete stand is considerably higher than that envisaged by the model.

There are 296.57 m³/ha of the growing stock of fir and spruce, which is 13% higher than the stock envisaged by Klepac's normal model (70:40% with the maturity dimension of 70 cm).

The 1950 distribution of beech trees has a characteristic falling shape, which it also retains in 1960, but with a slight drop. The measurement of 1980 shows a considerable decrease in the number of trees in lower diameter classes and an increase in the number of trees in higher diameter classes. This trend continues in the next decade, which is testified by the measurement data of 1990. The situation in 1997 is similar to than in 1990, with the only difference being that medium thick trees are a little better represented than in 1990, and that there are fewer trees in the diameter class of 51-60 cm than in 1990.

In relation to the proposed model, there is also a shortage of thin trees and a distinct surplus of medium thick trees. This has resulted in the growing stock of beech in the concrete stand being double than the growing stock in the proposed model (101%).

The total number of trees in 1950 and 1960 is almost equal in all diameter classes. After that the number of trees in lower diameter classes decreases and that in the higher classes increases (visible in the 1980 measurement). This trend continues in the following decade, while the measurement of 1997 shows the distribution similar to that from 1980, but with a significantly higher number of trees in the diameter class of 41-50 cm. The total growing stock is 32% higher than the normal stock.

This stand can be considered a well-managed selection forest with a surplus of beech trees in the diameter classes of 31-40 and of 41-50 cm and fir trees in the diameter class of 41-50 cm, and a deficit of thin beech trees.

A more intensive cutting of fir and especially beech in those diameter classes in which they are over-represented should decrease the surplus growing stock and approach the distribution by tree number to the model.

Sub-compartment 39c. According to the measurement of 1997, the number of fir trees in the diameter class of thin trees is 3-3.5 times lower than in the proposed model. This difference decreases with an increase in the diameter. The stand is characterised by a large number of trees above 70 cm of breast diameter (the distribution ends in the diameter class of 91-100 cm). The growing stock is higher than the stock in the model by about 10%.

With regard to the situation in past measurements, the distribution in the first measurement (1957) is the closest to the model. At that time, the deficit of the trees in lower diameter classes was much smaller (20-30%). The diameter class of 41-50 cm and higher diameter classes were already overrepresented at that time, but the distribution ended with the diameter class of 71-80 cm. Since then, the distribution has been falling along its entire length and has progressed to the right.

Today, beech is characterised by a shortage of thin and a surplus of medium thick and thick trees. A decrease in thin trees and an increase in medium thick and thick trees, with some slight deviations, are visible throughout the observed period. The growing stock exceeds the model by 35%.

Taken as a whole, the stand today has a deficit of thin and medium thick trees and a surplus of thick trees. The total growing stock is higher by 15.5% than the stock envisaged by the normal model.

Sub-compartment 61b. In this stand, the distribution of the tree number is even more unfavourable than in sub-compartment 39c. The distribution of fir trees, based on the 1997 measurement, has a shape of a prolonged (flattened) Gauss's distribution. Thus, the number of trees in the lower diameter classes is 5-10 times smaller than in the model. The class of medium thick trees is also underrepresented, but the class of thick trees is vastly overrepresented. The distribution ends with the diameter class of 91-100 cm. Similarly to sub-compartment 39c, the situation was slightly more favourable in 1957. The number of trees in lower diameter classes is two times lower than the number of trees in the model. The diameter class of 41-50 cm and higher diameter classes were overrepresented even then, but the distribution ended with the diameter class of 71-80 cm. Since then, the distribution has decreased in almost the entire length and has been prolonged to the right.

The growing stock exceeds the stock envisaged by the model by 23.5%.

Today, beech is characterised by a shortage of thin and a distinct surplus of medium thick and thick trees. According to the 1957 measurement data, the situation was different then. The class of thin trees was overrepresented, while the class of medium thick and thick trees was underrepresented. The growing stock exceeded the stock from the model by 48.6%.

Taken as a whole, the stand presently contains a shortage of thin and medium thick trees and a surplus of thick trees. The total growing stock exceeds the stock in the model by 31%.

By comparing the distribution of the tree numbers of other stands in the EMT I-C-10b with Klepac's mixed normal model containing the species mix 70:40 for both management units, I found that the condition of these stands was similar to that in the measured stands. The stands in the MU "Milanov Vrh" have a more or less selection structure, and the stands in the MU "Crni Lug" have a mostly transitional structure.

Our activities in the forest should be aimed at retaining the selection structure in the stands of the MU "Milanov Vrh" and approaching the proposed model as closely as possible. Taking into account the changes in the stand condition (species mix, increment, health status) and comparing them with other stands, the model will be adjusted in order to achieve the highest profit, at the same time maintaining the ecological stability and applying selection management.

In the stands that have lost their selection structure, as is the case with the stands in the MU "Crni Lug", the "left side of the distribution by tree number should first be lifted" by removing overmature trees. In other words, by ample and permanent natural regeneration (if possible) a sufficient number of thin trees, the trees of the future, should be ensured.

The poor structure of these stands after the Second World War was made even worse by inadequate management procedures. The introduction of the cluster management system meant that a part of the stands was not treated for a long time. The clusters did not regenerate, which led the structure in these stands to move even further away from the selection structure.

According to Matić (1979), the growth of pure fir stands at the expense of beech, which had been cut in favour of fir in the past, as well as the surplus of the growing stock of fir per hectare and an excessive number of trees in higher diameter classes led to a disturbed selection structure. Matić *et al.* (1996) say that the present condition of selection fir forests is characterised by a disturbed and frequently disappearing selection structure, which in turn causes a series of changes (very poor or completely absent natural regeneration of fir; a decrease or an increase in the growing stock in relation to the normal stock accompanied by a decrease in the increment; ageing, physiological weakening and dieback of dominant trees; distinct negative impacts of acid rains and other air, water and soil pollutants; changes in a stand's microclimate; degradation of forest soil by weed cover, a decreased microbiological activity, erosion or accumulation of raw humus; the occurrence of secondary pests that accelerate tree dieback; aggressive onset of beech at the expense of fir, and an artificial increase in the proportion of spruce). The authors mention the causes of such a condition: misapplied silvicultural treatments, particularly those related to the cutting cycle, cutting intensity and methods; longer dry periods in the global climate; unfavourable impacts of acid rains and pollutants that pollute the air, water and soil.

Every 10 years, new forest management activities provide feedback on the success of management. Therefore, planning in forestry should be regarded as a permanent process or a never-ending activity, while forest management should be viewed as a permanent learning process (Gašperić 1987).

In managing selection forests, the O-3 form is completed for every stand. Apart from the general stand data (area, site class, canopy, cover, inclination, etc.) and the description of the site and stands, the form also contains numerical data showing the condition of the stand (growing stock, increment, distribution per number of trees, etc.).

Permanent observation and comparison with the model, as was done in this paper in figures 5-16, provides data on the success of management at the stand level.

The distribution by tree number, as a direct measurable element of a stand structure, served as a basis for comparing the collected models, for observing the selected stands and for comparing them with the proposed model. It is also possible to monitor and compare other structural elements, but account should be taken of some possible limitations (for example, the application of different tables in estimating the growing stock of a stand (Božić 2000)).

The task of forest management is to prepare adequate solutions for a variety of problems occurring in this field (Gašperić 1987). In solving a certain problem, a manager should cooperate with relevant experts. Cooperation between the manager and the one who manages the forest directly - the district ranger - silviculturalist - is the most important.

A graphic presentation of the structure of tree numbers (before cutting) and its position in relation to the normal model (after cutting) can greatly help a silviculturalist to select trees to be cut. When in doubt which tree to leave and which to cut, it may serve as a guideline and may provide information about which diameter degrees or classes are underrepresented or overrepresented.

The structure of the trees at the time of cutting can be obtained from the structure at the time of management and from the data on conversion times or diameter increment of individual diameter degrees (from management plans), in the same way in which it is done in calculating the structure during mathematical revision of management plans.

CONCLUSIONS
ZAKLJUČCI

The following conclusions may be drawn from research results and discussion:

1. The normal models from the end of the last and the beginning of this century represent, according to Liocourt's law, an adjusted situation in the forest. From the present standpoint, they are characterised by a high growing stock before cutting, long cutting cycles and a low annual and high periodical cutting intensity.
2. Frequency curves of the number of trees in almost all the studied "old" models are higher than Klepac's curves for the II site class in their entire range (pure fir - situation before cutting).
3. The frequency curve of the Institute's normal model in the ecological management type I-C-10b in relation to the equivalent Klepac's normal model is higher in almost

the entire range. Deviations of the Institute's model from Klepac's model (expressed in percentages) are the highest in the 10-20-cm diameter class, and slightly lower in the diameter class of 21-30 and of 61-70 cm.

4. The application of the normal model by EMT is not recommended, because it was constructed for a certain site class (I-C-10b-II site class of fir and the II site class of beech), and the stands selected in the type belonged to different site classes in the old management plans. The stands classified in the EMT I-C-10b were in a wide range of site classes, the fir of I/II to IV, and the beech of II to V.
5. The studied stands in the MU "Milanov Vrh" have a more or less selection character, while the stands in the MU "Crni Lug" have transitional forms (neither regular nor selection).
6. In all the stands under research, the number of medium thick and thick trees increased and that of thin trees decreased over time (from 1950-1997). A drop in the number of thin trees is particularly distinct in the stands of the MU "Crni Lug", because the number of trees in this diameter class was deficient in the first measurement as well.
7. An increase in the number of medium thick and thick trees has led to an increase in the growing stock.
8. In relation to the proposed models, the growing stock proved overabundant in all the stands under study.
9. The surplus of the growing stock can be considered one of the main causes of the deficit of trees in lower diameter classes.
10. Klepac's normal model, constructed with h_{dom} and used by himself, is recommended for the management of selection forests for relevant site classes and the species mixes to be achieved in stands (Božić & Čavlović 2001).
11. In order to obtain data on the success of management with these forests, it is necessary to monitor changes, at the stand level, in the position of breast diameter distributions by tree species in relation to past distributions and in relation to the model.
12. The cutting maturity diameter for fir in uneven-aged stands is determined by the span from 50 to 70 cm (according to the Forest Management Regulation). The cutting maturity in any one stand should be determined on the basis of the quality of the previously cut thick trees. This prevents the cutting of healthy and good quality trees in the prime of their growth.
13. Before regular marking, the distribution by tree numbers in the year of marking should be calculated with the mathematical revision method and compared with the model after cutting in order to find out in which diameter degree some tree species are overrepresented.
14. In drawing up management plans, forest rangers and other expert staff that manage a particular forest should assist managers, because they are the ones who have the best knowledge of this forest.
15. An expert managing a forest should keep a forest chronicle containing his observations on individual stands while the management plan is in force, and keep a record of the cut trees by tree species, years of cutting, distribution of cut trees by diameter classes

and the reasons why some trees have been cut. These data will be used by a manager in producing future management plans.

16. In regulating selection stands, more attention should be paid to future trees, that is, thin trees (10-30 cm) and trees below the taxation limit.
17. By monitoring the changes in a stand condition and the procedures leading to these changes (at the stand level) over a period of time, we will receive feedback on the species mix, the value of the stock and its distribution, which could represent a more favourable model than the one used currently.

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PRIMJENA MODELA PRI UREĐIVANJU JELOVIH ŠUMA GORSKOGA KOTARA

SAŽETAK

Jelove šume Gorskoga kotara uređivane su prema različitim metodama. Njima se gospodarilo različitim metodama i različitim intenzitetom s obzirom na vlasništvo nad njima. Danas se ovim šumama gospodari preborno, pri čemu osobitu pozornost treba posvetiti unutrašnjoj strukturi sastojine, odnosno raspodjeli broja stabala, temeljnice ili drvne zalihe po debljinskim stupnjevima (razredima). Raspodjela broja stabala po debljinskim stupnjevima odvija se prema Liocourtovu zakonu postupnoga i pravilnoga smanjivanja broja stabala s jačim debljinskim stupnjem, te pri grafičkom prikazu ima oblik hiperbolične krivulje.

U dosadašnjem gospodarenju ovim šumama primjenjivani su različiti modeli koje se nastojalo izgospodariti, a najveći dio tih modela izlazi iz metode normala. U vremenu od početaka uređivanja ovih šuma do danas pri uređivanju su primjenjivani modeli iz nekoliko izvora: Metode normala prije i poslije sječe (propisane Naputkom iz 1903), "Novi sistem uređivanja prebornih šuma" Dušana Klepca te institutski EGT-ovi.

Normale odnosno modeli nastali iz Metoda normala prije i poslije sječe većinom su korekcija nalaza u šumi, te je tako korigirana krivulja broja stabala bila model ili normala. Normale prije sječe Miletić (1957), prema njihovu postanku, dijeli na:

1. Realne – na osnovi podataka dobivenih iz same preborne šume
2. Teoretske – na osnovi određenih pravilnosti i postupnosti primijećenih kod normalnih sastojina; na osnovi elemenata prikupljenih u prebornoj šumi koju uređujemo
3. Kombinirane.

Normale nastale uređivanjem naših šuma mahom su realne normale. S obzirom na način kako su nastale, Miletić ih (1957) dalje dijeli na:

1. Slobodne normale — nastale nalazom na manjim površinama tipičnih sastojina
   a) izvedene iz čiste preborne sastojine
   b) izvedene iz mješovite preborne sastojine
2. Deduktivne normale – nastale kao prosjek više primjernih površina;

3. Strane normale – normale uzete sa strane te prilagođene stvarnim prilikama šume.

U slučaju da se u šumi, zbog nedavne sječe ili nekoga drugoga razloga, ne može naći normala prije sječe, pri uređivanju tih šuma upotrebljavale su se strane normale ili se pak konstruirala normala tako da su se na plohama gdje se normala tražila izmjerili elementi strukture, procijenio obrast, te su se izmjereni elementi korigirali na potpun obrast.

Stanje je poslije sječe određivano empiričkim putem, ponavljanim pokusima. Za sječu je bio predviđen cijeli zadnji debljinski razred te dio stabala iz ostalih debljinskih razreda (prekobrojna). Majnarić poslije odstupa od ovoga pravila te za sječu ne predviđa cijeli zadnji debljinski razred, nego njegov veći dio (u normali za šumu bivše zamljišne zajednice Drivenik za sječu predviđa 90 % zadnjega debljinskoga razreda). Normala se smatrala pravilno postavljenom ako je bio ostvaren glavni uvjet, a taj je da se po isteku određene ophodnjice uspostavi normalno stanje prije sječe u svim elementima strukture.

Osim što su drvne zalihe prije sječe koje su normalama predviđene bile visoke, prirast se normala određivao na osnovi stanja poslije sječe. Ni tako određen prirast nije u potpunosti bio predviđen za sječu jer su se ostavljale određene zalihe kao osiguranje za slučaj nepredviđenih sječa. Kako stvarnu proizvodnu snagu normale čini prosječni godišnji volumni prirast (aritmetička sredina prirasta prije i poslije sječe) te zaliha stabala uraslih u mjerljivi dio sastojine, jasno je da se zbog sječe, koja je manja i od prirasta zalihe poslije sječe, nagomilala drvna zaliha po jedinici površine.

Normalno stanje preborne šume Klepac zasniva na temeljnom nizu stabala različitih debljina, od kojih svake godine jedno stablo dostigne dimenziju zrelosti, i na više upotpunjavajućih nizova koji nadomještaju prirodnom ili umjetnom selekcijom izlučena stabla. Klepčeve normale nastale su na temelju visine dominantnih stabala te Susmelovih korelacija za jelu i Coletteovih za bukvu. Normala je konstruirana za stanje između dviju prebornih sječa, dok se stanje prije ili poslije sječe dobiva dodavanjem odnosno oduzimanjem l/2 godišnjega prirasta (l – duljina ophodnjice).

Normale po ekološko-gospodarskim tipovima (EGT) nastale su prilagodbom Klepčevih normala utvrđenim tipovima šuma, gdje tip upućuje na mogućnosti nekoga područja.

Iz međusobnoga položaja krivulja broja stabala "starih" normala i normale istraživanoga EGT-a I-C-10b prema adekvatnim Klepčevim normalama (slike 3 i 4) vidljivo je da je kod većine starih normala krivulja broja stabala iznad Klepčeve krivulje, s tim da su ta odstupanja značajnija (u %) u nižim i višim debljinskim razredima. To je posljedica stanja tih šuma u vrijeme uređivanja (kraj prošloga i prvih nekoliko desetljeća ovoga stoljeća) kada se u njima nalazila nagomilana drvna zaliha kao posljedica ekstenzivnoga gospodarenja. Jedan dio ovih modela nastao je uz pretpostavku jednakosti temeljnica svih debljinskih razreda (koju i autori tih modela poslije odbacuju kao nerealnu) te je zbog toga odstupanje ovih modela od Klepčeva najizraženije u najnižim debljinskim razredima. Ovdje je zanimljiva činjenica da se postotno odstupanje institutske normale EGT-a I-C-10b, korigiranoga za čistu jelu, stanje prije sječe cijelim svojim rasponom gotovo preklapa s Jovanovčevom normalom za zemljišnu zajednicu Benkovac iz 1912, koja je nastala na pretpostavci jednakosti temeljnica svih debljinskih razreda. Osim toga unutar EGT-a, koji je predstavljen jednim modelom, nalazile su se sastojine širokoga raspona bonitetnih razreda, jela I/II-IV, a bukva II-V. Na temelju tih činjenica prilikom uređivanja jelovih prebornih šuma preporučuje se upotreba Klepčevih normala (modela), i to originalnih Klepčevih normala da bi se izbjeglo umjetno snižavanje visine dominantnih stabala zbog sječe stabala iznad određene dimenzije zrelosti i različita definiranja dominantne visine pojedinih autora (Božić i Čavlović 2001).

Istraživane sastojine GJ "Milanov vrh" manje-više su prebornoga karaktera, dok su istraživane sastojine GJ "Crni lug" prelaznih oblika (ni regularne ni preborne).

U svim istraživanim sastojinama s vremenom se (1950–1997) povećao broj srednje debelih i debelih stabala, a smanjio broj tankih stabala (što je vidljivo na slikama 5–16). Smanjenje broja tankih stabala osobito je došlo do izražaja u sastojinama GJ "Crni lug", jer je broj stabala u tom debljinskom razredu bio deficitaran i prema prvom mjerenju. Zbog povećanja broja srednje debelih i debelih stabala povećana je drvna zaliha.

Drvna je zaliha u odnosu na predložene modele u svim istraživanim sastojinama previsoka. Previsoku drvnu zalihu možemo smatrati jednim od glavnih uzroka deficita broja stabala u nižim debljinskim razredima.

Distribucija broja stabala, kao neposredni mjerljivi element strukture sastojine, bila je onaj element na temelju kojega sam uspoređivao prikupljene modele, te protekom vremena promatrao odabrane sastojine i uspoređivao ih s predloženim modelom. Promatrati odnosno uspoređivati može se i neki drugi element strukture, s tim da se pri usporedbi treba voditi računa o mogućim ograničenjima (npr. primjena različitih tablica za određivanje drvne zalihe sastojine /Božić 2000/).

Radi dobivanja podataka o uspješnosti gospodarenja tim šumama potrebno je na razini sastojine pratiti promjene položaja distribucije prsnih promjera po vrstama drveća i ukupno u odnosu na prijašnje distribucije i u odnosu na normalu (model).

Promjer sječive zrelosti u raznodobnim sastojinama za jelu određen je rasponom od 60 do 70 cm (prema Pravilniku za uređivanje šuma). Sječivu zrelost u svakoj pojedinoj sastojini treba odrediti na temelju kakvoće ranije posječenih debelih stabala. Ovim bi se spriječilo da se sijeku zdrava stabla u naponu prirašćivanja.

Prilikom grafičkoga prikazivanja stanja sastojine i odnosa prema normali treba prikazati normalu uz najnižu dimenziju zrelosti i fiziološku zrelost.

Prije redovite doznake, metodom računske revizije, treba izračunati distribuciju broja stabala u godini doznake, te je usporediti s normalom poslije sječe da bi se dobio uvid u kojem su debljinskom stupnju stabla pojedinih vrsta drveća prezastupljena ili premalo zastupljena. Taj podatak može dobro poslužiti revirniku kao putokaz prilikom doznake, ako se nađe u nedoumici koje stablo ostaviti, a koje posjeći.

Prilikom izrade osnove gospodarenja revirnik i ostalo stručno osoblje koje tom šumom gospodare, trebali bi biti na raspolaganju uređivačima, jer oni ipak dotičnu šumu najbolje poznaju.

Stručnjak koji konkretnom šumom gospodari treba voditi šumsku kroniku, u koju bi bilježio svoja zapažanja o pojedinim sastojinama tijekom važenja osnove gospodarenja, te evidenciju posječenih stabala po vrstama drveća, godinama sječe, raspodjeli posječenih stabala po debljinskim stupnjevima, kao i razlozima zbog kojih su pojedina stabla posječena. Ti će podaci dobro doći uređivaču prilikom izrade iduće osnove gospodarenja.

Prilikom uređivanja prebornih sastojina veću pozornost treba posvećivati stablima budućnosti, tj. stablima ispod taksacijske granice.

Protekom vremena, praćenjem promjena stanja u sastojinana i postupaka koji su do tih promjena doveli (na razini sastojine) zasigurno ćemo, kao povratnu informaciju iz šume, dobiti podatke o omjeru smjese, vrijednosti zalihe, njezinoj distribuciji koji bi za promatranu sastojinu predstavljali povoljniji model (normalu) od dotada rabljenoga.

Ključne riječi: Gorski kotar, uređivanje šuma, modeli