

Status and development of forest harvesting mechanisation in Croatian state forestry

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Abstract – Nacrtak

This paper deals with the present status of forest management in the Republic of Croatia with a special reference to forests managed by the company »Hrvatske šume« d.o.o. Zagreb, as well as to aims, tasks and methods of state-owned forest management, to conditions and trends in the number of the most significant forest machines used so far in forest harvesting. Also, the ways and activities are described by which »Hrvatske šume« d.o.o., in cooperation with the Faculty of Forestry, University of Zagreb, influence the trend of machine and technology development, as original solutions for meeting particularly demanding conditions of natural forest management.

In the Republic of Croatia, the state owns 75% of the total area of forests and forest land, i.e. 2,018,987 ha are managed by »Hrvatske šume« d.o.o. »Hrvatske šume« d.o.o. carry out more than 50% of forest management activities by their own production forces and means. Therefore, the development of machines and technologies is a very significant precondition for improving business efficiency in severe terrain conditions, characterised by specific management methods. Four main criteria of suitability requirements, i.e. suitability of technical-technological solutions, can be singled out:

- ⇒ Environmental suitability
- ⇒ Efficiency
- ⇒ Safety
- ⇒ Ergonomic suitability.

These criteria have partly been established in line with modern international standards, applicable to conditions in the Republic of Croatia and partly by specific features of management conditions. The influence of »Hrvatske šume« on meeting the above requirements, and direct participation of »Hrvatske šume« in the development of technical-technological solutions suitable for certain conditions, have been shown on examples of development of two types of skidders and tractor assemblies for lowland forest thinning. Efforts are made to meet these requirements through tasks of the scientific-research work projects and in cooperation with the Faculty of Forestry, University of Zagreb, as well as by placing demands on and in cooperation with domestic manufacturers of machines and equipment.

Keywords: *Hrvatske šume d.o.o., natural forests, development of machines and technologies, skidders, tractor assemblies*

1. Introduction – Uvod

»Hrvatske šume« d.o.o. Zagreb is a company in charge of the management of forests and forest lands owned by the Republic of Croatia, in accordance with the Forest Act (Official Gazette 140/2005). Since forests and forest land are exceptionally significant natural resources, they are under special protection of the Croatian state, which chose sustainable development of these resources in accordance with pan-

-European measures and recommendations of modern forest science and profession. Nowadays, some especially important pan-European criteria for such a sustainable management refer to the care of forest ecosystems as significant contribution to global carbon cycle, water and soil protection and their favourable influence on current climate conditions, support of biological diversity and landscape specifics, increase of forest ecosystem efficiency related to the production of forest biomass and other generally useful be-

nefits, as well as improvement and protection of other socio-economic functions of forest.

Such a demanding forest management, which implies primarily the maintenance of natural features and stability of forests and other ecosystems could not be performed without preservation and support of autochthonous species in regeneration, care and use of forests as means and ways of creating preconditions for ensuring the optimal natural site conditions. A forest management method significantly influences the development of tools for work and applied procedures, while the specific features of work conditions demands complex and special work procedures and technologies. Therefore, the development of forestry machines of the Republic of Croatia was under a strong influence of the management method and working conditions characterised by exceptionally uneven forest stand conditions in the whole area. The same factors are closely related to forest infrastructure, which refers to the forest road network of various degrees of openness, as well as traffic purpose and significance.

2. Forest management in the Republic of Croatia – *Gospodarenje šumama u Republici Hrvatskoj*

Thanks to a long-standing forest tradition, in which the relation towards forest management has been based on scientific-professional principles since old times, the natural structure and stability of forests have been almost entirely kept to the present day in

the Republic of Croatia. This tradition is based on organised management of forest stands, which started in Croatia at the same time as in the most developed parts of Europe. Thus, forest offices as terrain organisational units, in which the basic manufacturing-professional activities of forest and forest land management have been carried out, were established for the first time in these areas as early as 1767, i.e. almost 240 years ago. The first three forest offices in the area of today's Croatia were as follows: forest office of Krasno, Oštarije and Petrova Gora.

According to the data of the Forest Management Plan of the Republic of Croatia for the period 2006–2015, 42% of the state land area in the Republic of Croatia is covered by various forms of forest vegetation (24,028 km²), of which state ownership accounts for 78% and private ownership for 22%. A part of state forests is also used by other legal and economic entities pursuant to regulations on protected parts of forest vegetation (national parks) or certain provisions regulating the purpose of forest use, such as military requirements, scientific research, water-management activities and some other purposes.

It can be seen from the share in growing stock that the growing stock in state forests is higher than in private ones, as the result of inadequate management in private forests in the period after the end of the Second World War, primarily due to the system which favoured social ownership, and also due to great fragmentation of private forest property and hence impossibility of application of profitable technologies in their management.

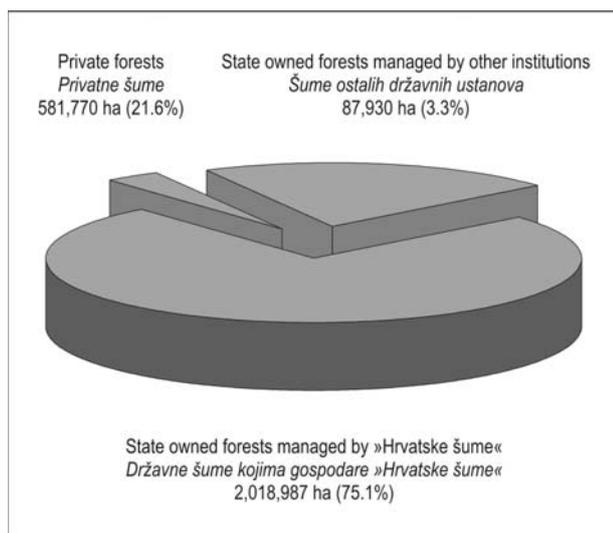


Fig. 1 Forest and forest land ownership structure in the Republic of Croatia by percentage share

Slika 1. Vlasnička struktura šuma i šumskoga zemljišta u Republici Hrvatskoj prema udjelu u površini

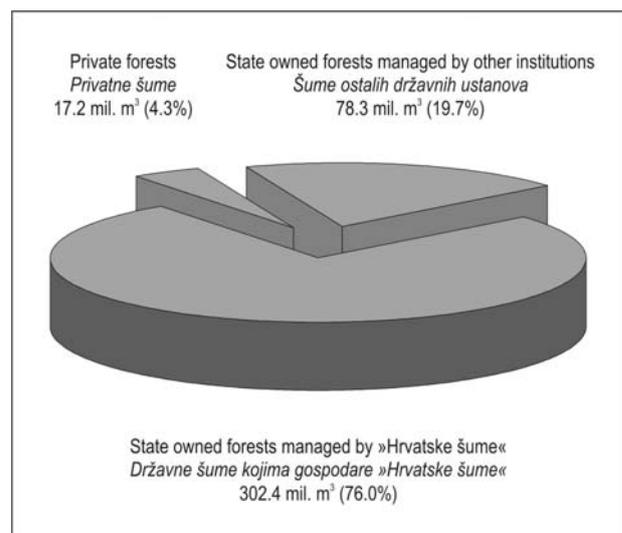


Fig. 2 Ownership structure of forests in the Republic of Croatia by share in growing stock

Slika 2. Vlasnička struktura šuma u Republici Hrvatskoj prema udjelu u drvnjoj zalihi

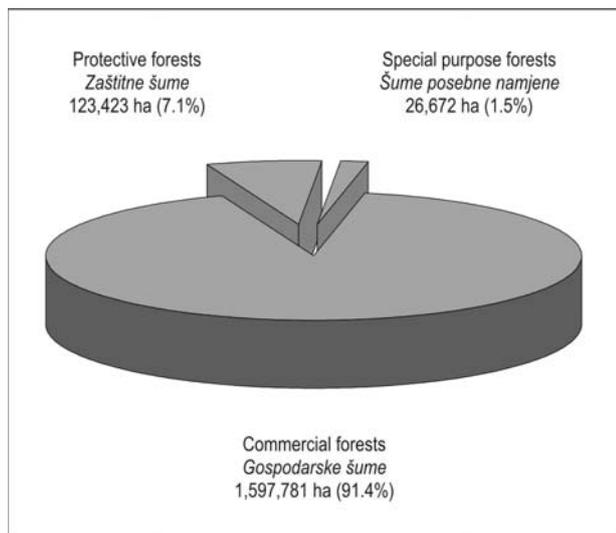


Fig. 3 Structure of forests according to their purpose (forests managed by »Hrvatske šume« d.o.o.)

Slika 3. Struktura šuma prema namjeni (šume kojima gospodare »Hrvatske šume« d.o.o.)

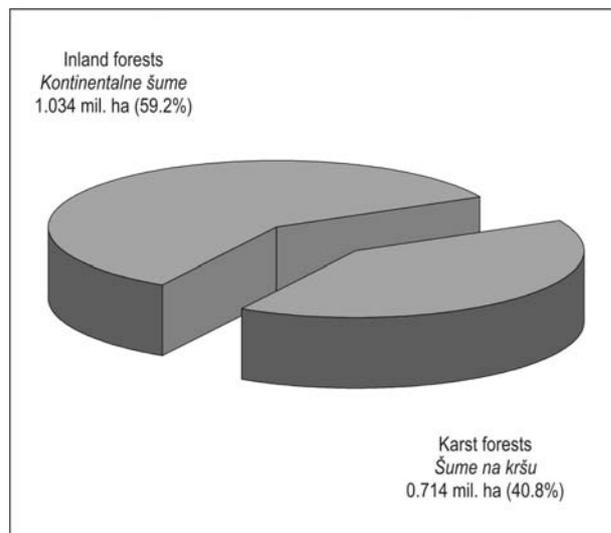


Fig. 4 Structure of forests by geographical position (forests managed by »Hrvatske šume« d.o.o.)

Slika 4. Struktura šuma prema zemljopisnom položaju (šume kojima gospodare »Hrvatske šume« d.o.o.)

91% of all forest areas managed by »Hrvatske šume« d.o.o. refers to commercial forests, 7% are protective forests, while 2% are special purpose forests.

Commercial forests, apart from the basic task of protecting and improving their functions of general benefit, are primarily used for timber production. The purpose of protective forests is primarily the protection of land, water, settlements, facilities and other goods, while the special purpose forests are used for controlled production of forest seeds, scientific research, defence requirements of the Republic of Croatia, purposes regulated by special regulations or they belong to protected parts of nature under special legal protection.

Most state forest areas (59%) are situated in the so-called continental part of the Republic of Croatia, in the hinterland and primarily comprise even-aged and selective commercial forests, while about 41% of mostly degraded forms of forests are located in the coastal area along the Adriatic sea (littoral karst forests) or belong to a part of the so-called high karst, a bit distant from the coastal area and higher areas of hinterland, leaning on or entering the areas of forests with selective management method.

Figure 6 shows that the main species of trees in forests managed by »Hrvatske šume« d.o.o., as well as in the whole Croatia, are beech trees with the growing stock of 113 mil. m³, pedunculate oak with 45 mil. m³, and sessile oak with 29 mil. m³, together making 61% of the total growing stock. The most valuable species of trees in the forests of the Republic

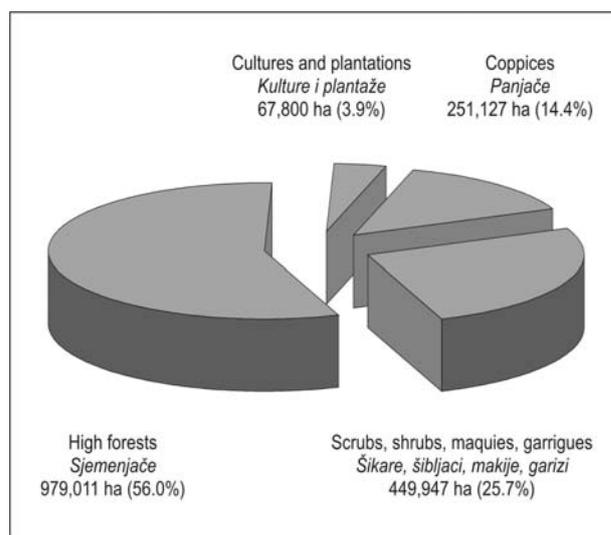


Fig. 5 Silvicultural forms of forests (covered areas managed by »Hrvatske šume« d.o.o.)

Slika 5. Uzgojni oblici šuma (obrasle površine kojima gospodare »Hrvatske šume« d.o.o.)

of Croatia is pedunculate oak (*Quercus robur* L.) of a well known quality and very demanding management conditions.

It can be seen from the relation between the annual increment of the growing stock and annual allowable cut regarding tree species (Fig. 7 and 8) that this relation is mostly observed by the three main commercial tree species: pedunculate oak, ses-

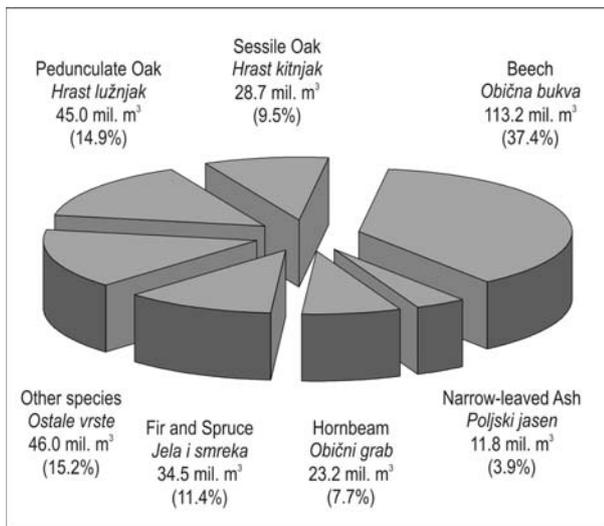


Fig. 6 Growing stock by tree species (forests managed by »Hrvatske šume« d.o.o.)

Slika 6. Drvena zaliha prema vrstama drveća (šume kojima gospodare »Hrvatske šume« d.o.o.)

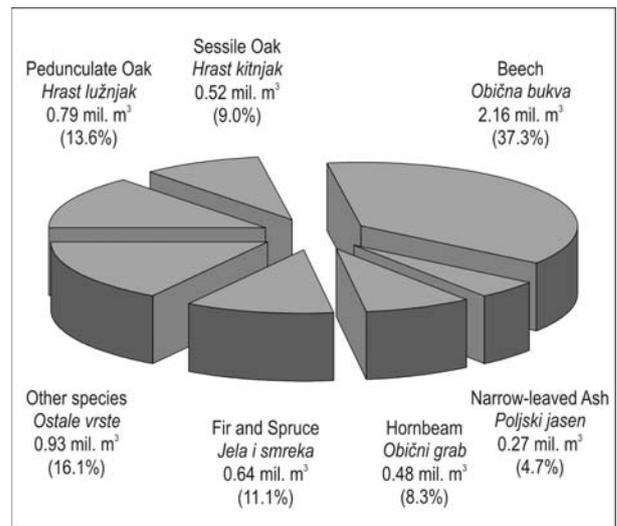


Fig. 8 Annual allowable cut by tree species (forests managed by »Hrvatske šume« d.o.o.)

Slika 8. Godišnji etat po vrstama drveća (šume kojima gospodare »Hrvatske šume« d.o.o.)

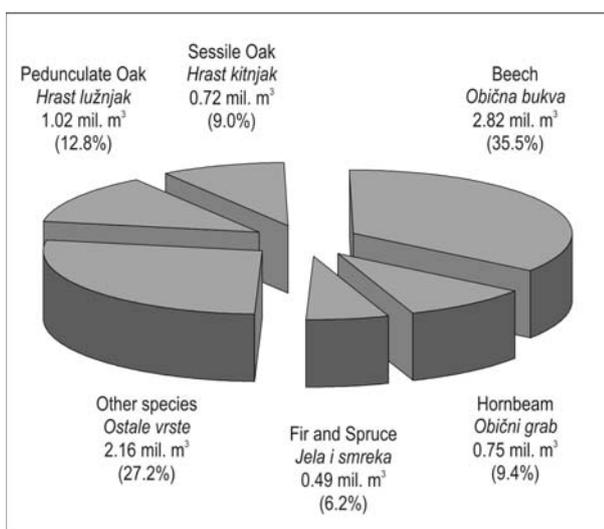


Fig. 7 Annual increment of the growing stock by tree species (forests managed by »Hrvatske šume« d.o.o.)

Slika 7. Godišnji prirast drvene zalihe po vrstama drveća (šume kojima gospodare »Hrvatske šume« d.o.o.)

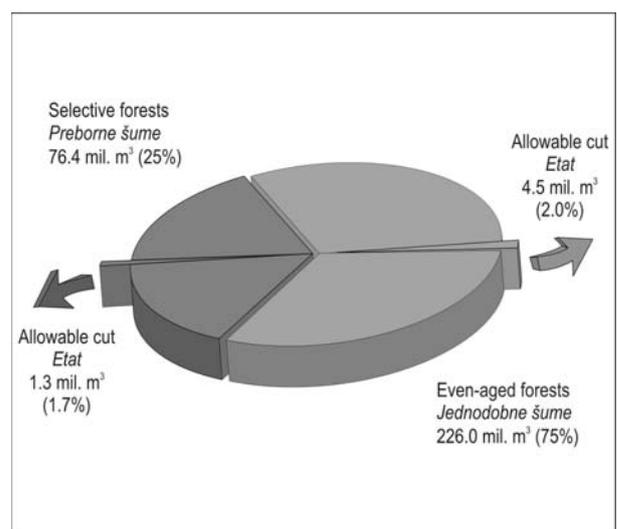


Fig. 9 Growing stock and allowable cut in even-aged and selective forests (forests managed by »Hrvatske šume« d.o.o. for the period 2006–2015)

Slika 9. Drvena zaliha i etat u jednodobnim i prebornim šumama (šume kojima gospodare »Hrvatske šume« d.o.o. za razdoblje 2006 - 2015)

sile oak and beech, whereby the annual allowable cut accounts for approximately 73% of annual increment (Fig. 10). As far as the management method is concerned, Figure 9 shows that the annual allowable cut in even-aged forests with respect to the growing stock of these forests is higher by 0.3% than the annual allowable cut with respect to the growing stock of selective forests.

Figure 10 shows total growing stock, annual increment and annual allowable cut in forests of the

Republic of Croatia, established by the new Forest Regional Economic Policy of the Republic of Croatia for the period 2006–2015. According to these data, it can be seen that the unit increment is much higher in private forests than in state ones, which is the result of the above mentioned unfavourable relations towards this ownership category in the period after the Second World War in these areas, as well as of fragmentation of such forest property. As far as the growing stock increment is concerned, similar rela-

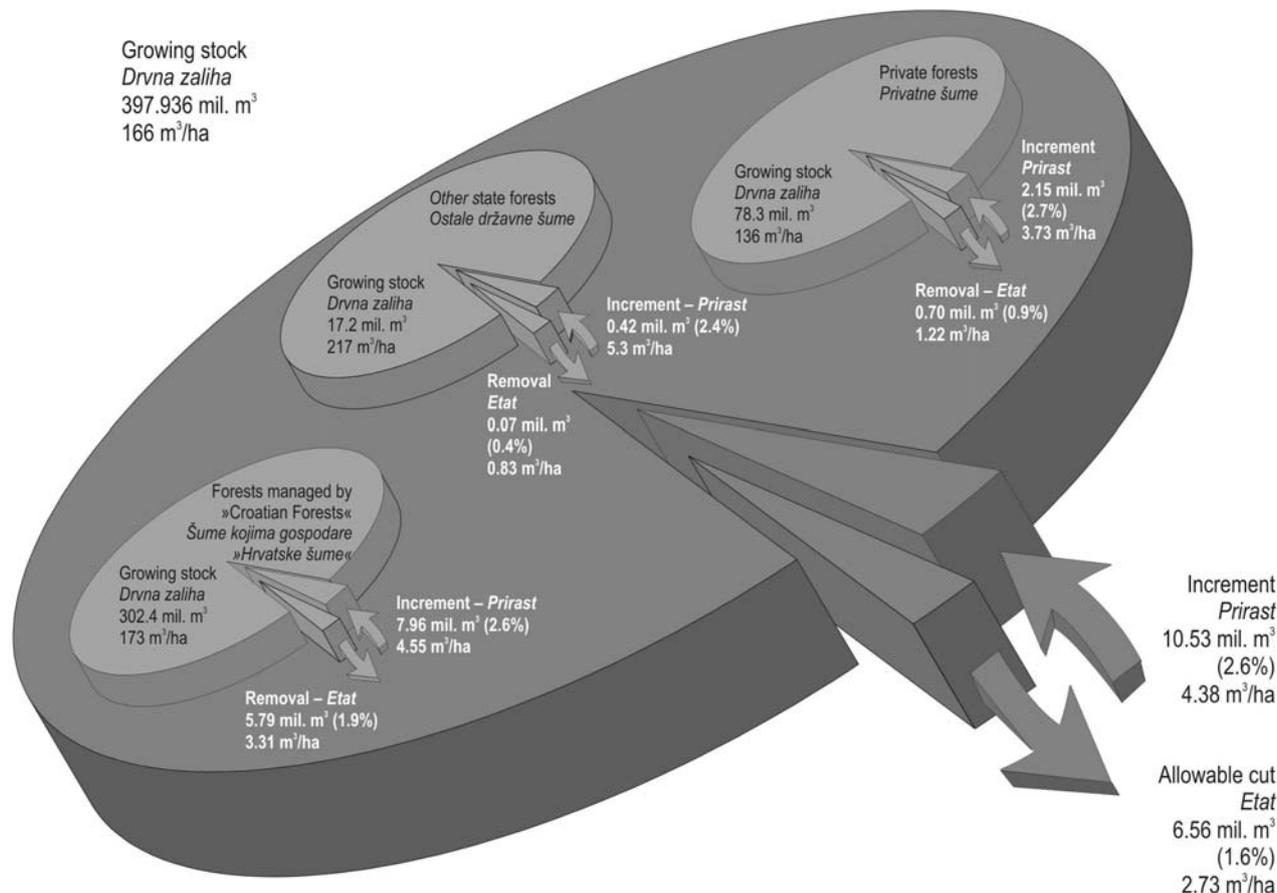


Fig. 10 Growing stock, annual increment and allowable cut of the Croatian forests in the period 2006-2015
Slika 10. Drvena zaliha, godišnji prirast i etat šuma Republike Hrvatske za razdoblje 2006 - 2015.

tions were observed regarding the volume of annual allowable cuts in private forestry. The new Forestry Act of the Republic of Croatia has created conditions for renewal of and higher investments into private forests with the aim of improving their structure and overall management.

3. Status and possibilities of development of machinery and technology in the management of state forests of the Republic of Croatia – Stanje i mogućnosti razvoja mehaniziranih sredstava za rad i tehnologija u gospodarenju državnim šumama Republike Hrvatske

The very beginning of work mechanisation in the forests of the Republic of Croatia can be identified with the beginning of use of farm tractors in the second half of the last century as a means of trans-

port and timber skidding and somewhat later (in the 60s) in establishing plantations of the Euro-American poplars. Since then many works, originally only performed manually, moved from the zero-state into the first degree of mechanisation by transformation into manual-machine works, like tree felling and processing (Sever 1993). Timber was mostly skidded by animals, and tractors were introduced into timber harvesting in order to ease hard work to people and animals. Although the beginning of use of farm tractors, together with the introduction of chainsaw for tree felling and processing, was in a way a turning point in the mechanisation of works in forest management in the Republic of Croatia, it cannot be considered the beginning of development of certain technologies of timber harvesting or silvicultural operations characteristic of specific work conditions, since these machines had many faults caused by their originally inadequate purpose (Horvat and Tomašić 1993). In early 1960s there were already more than 200 farm tractors working in the

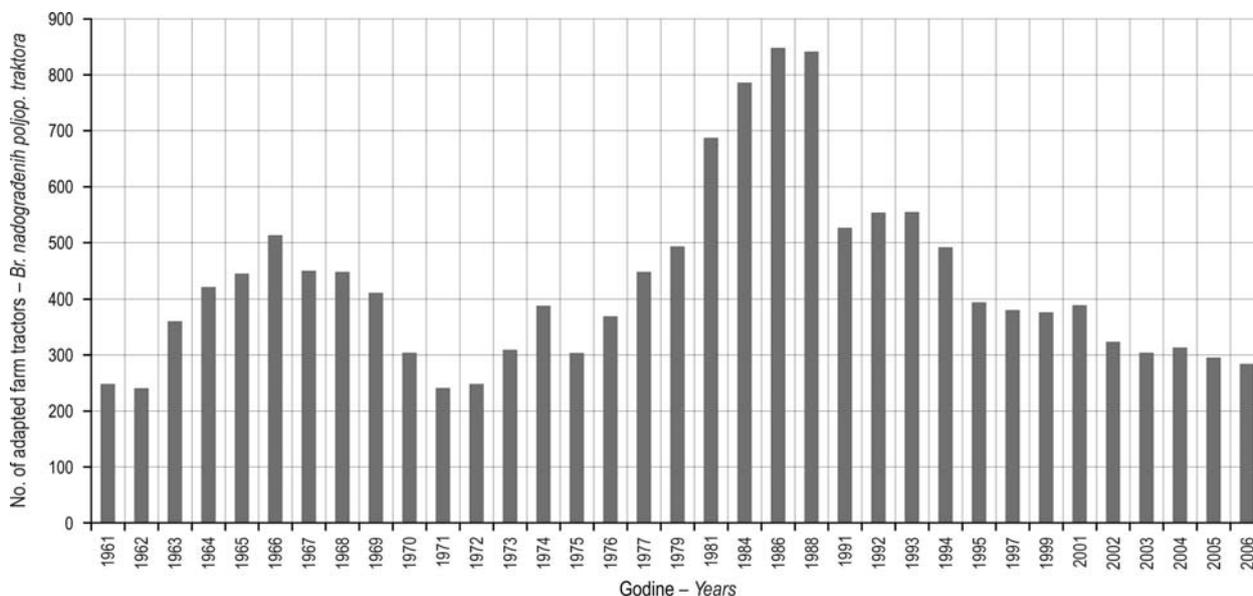


Fig. 11 Trends in the number of adapted farm tractors in state forestry of the Republic of Croatia in the period 1961–2006

Slika 11. Kretanje broja nadograđenih poljoprivrednih traktora u državnom šumarstvu Republike Hrvatske u razdoblju 1961 – 2006.

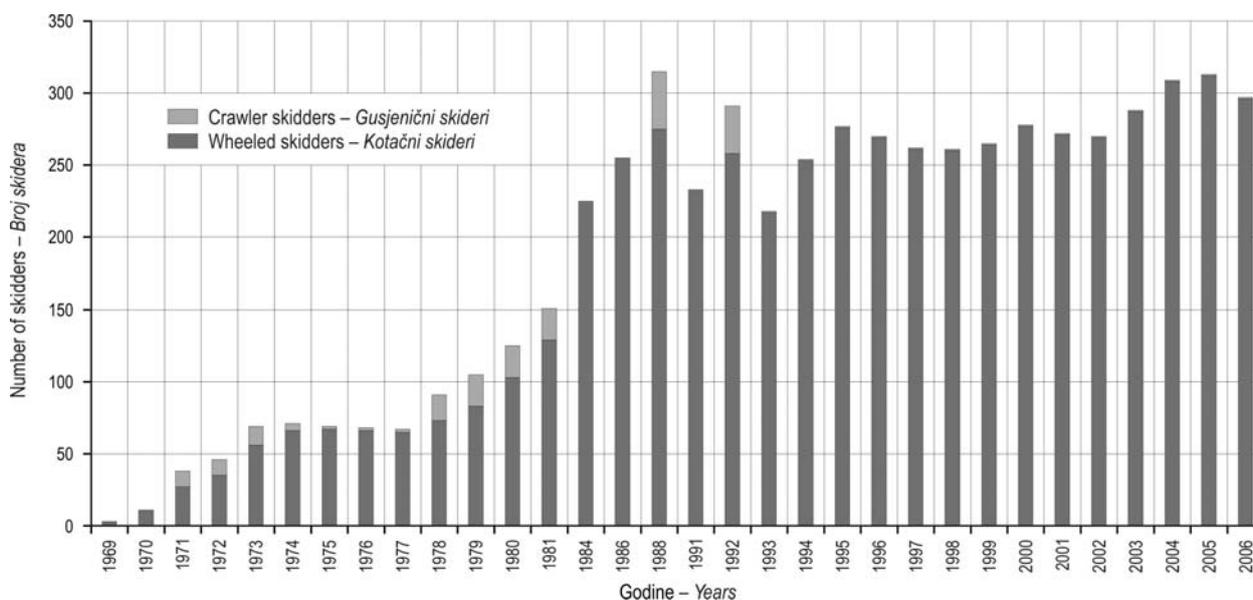


Fig. 12 Trend in the number of skidders in state forestry of the Republic of Croatia in the period 1969–2006

Slika 12. Kretanje broja skidera u državnom šumarstvu Republike Hrvatske u razdoblju 1969 – 2006.

Croatian forestry (Fig. 12). This figure shows that the number of farm tractors reaches the highest values in two periods: in mid-1960s and 1980s, while in late 1990s it significantly decreases, levelling off at the reached number of about 300, when a significant part of farm tractors was only used for silvicultural operations.

The moment of introduction of the first specialised machines, skidders and forwarders, in the Croa-

tian forestry in 1970s can be considered the beginning of designing and development of today's procedures in forest silviculture and forest harvesting, which primarily depend on natural characteristics of the forest area and silvicultural method (Beđula and Slabak 1974). Figures 12 and 13 show the trend in the number of skidders, i.e. forwarders in the forestry of the Republic of Croatia. It can be noted that the period of intensive mechanisation with these machi-

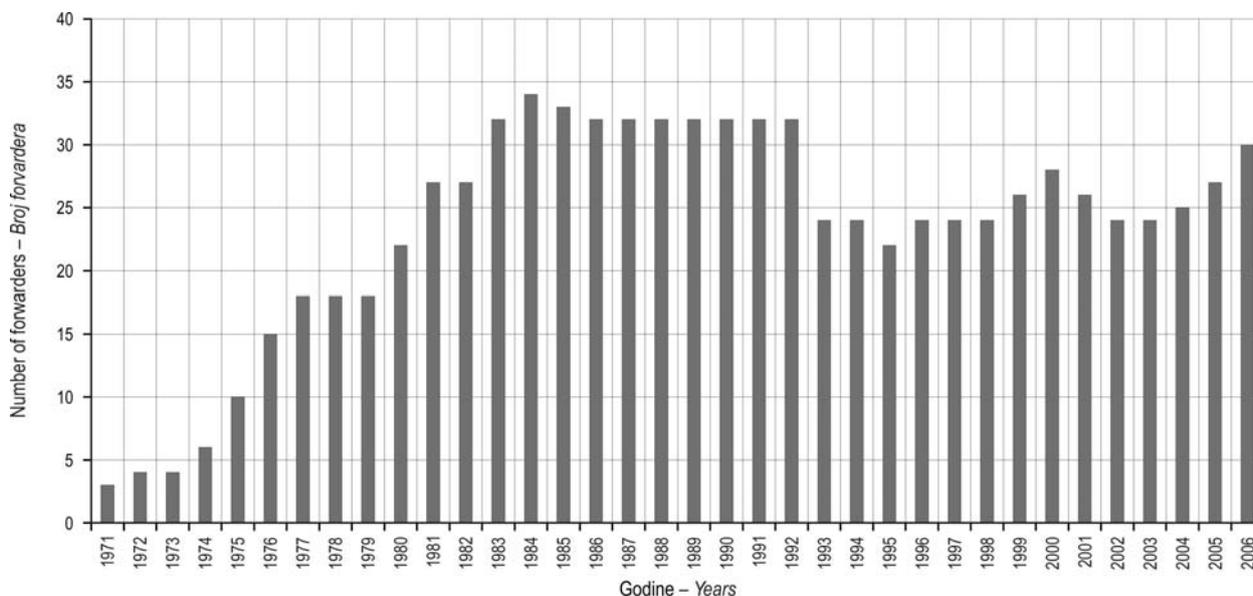


Fig. 13 Trends in the number of forwarders in state forestry of the Republic of Croatia in the period 1971–2006

Slika 13. Kretanje broja forwardera u državnom šumarstvu Republike Hrvatske u razdoblju 1971 – 2006.

nes started in early 1970s and lasted almost till late 1980s, when the achieved number started stagnating, with a mild increase in the last several years. The appearance of these specialised machines and technologies in the Croatian forestry does not lag significantly behind the trends in Europe and in the whole world.

More favourable features of these machines, whose exclusive purpose was timber skidding, provided by manufactures' design solutions, enabled the determination of procedures in performing individual (semi)phases of forest harvesting: felling, processing, skidding and transportation of wood due to close connection between procedures and choice or use of a specific technique.

In that way, the basic methods of forest harvesting were gradually developed in the forestry of the Republic of Croatia, and they were adapted to terrain and stand conditions (Krpan *et al.* 2003):

- ⇒ In regenerative felling of lowland forests, where the most valuable species is the pedunculate oak, a cut-to-length method is used in felling and processing, and forwarders are almost exclusively used for the removal of processed timber to the landing, wherever the soil is of sufficient bearing capacity. Timber is removed by forwarders on wheels since in that way much less damage is caused to seedlings than in ground skidding. In thinnings of these forests where a cut-to-length method of felling and processing is also used, timber is also

removed on wheels from the forest to the landing. However this operation is carried out by smaller machines, the so-called tractor assemblies, which consist of an adapted farm tractor, semi-trailer and loader which can also be equipped with a winch.

- ⇒ On sloping terrains in hilly areas, timber skidding is mostly performed by skidders in regenerative felling of even-aged forests and selective felling with the use of a half-length method of felling and processing, while in thinnings of even-aged forests of these areas, with the use of cut-to-length method of felling and processing, apart from middle thinning skidders, adapted farm tractors with winch are also used.

3.1 Felling and processing – *Sječa i izradba drva*

In Croatian forestry manual-machine work is used for felling and processing. Felling is carried out by chain saws. Chain saws are also used for delimiting, bucking and cutting. Machines for tree felling and processing are not used in Croatia. Their use in our country is mostly limited by natural origin of forests, wood species and tree dimensions, macrorelief and microrelief, methods of forest silviculture and management and others (Krpan 2000). The interest of the forestry profession in Croatia for a completely mechanised system of short wood skidding, which ensures a technological and manufacturing step forward from the usual procedures of forest harvesting,



Fig. 14 Thinning of hard broadleaved trees by harvester
Slika 14. *Proreda tvrdih listača harvesterom*

can be seen in two pilot trials of machine felling and processing carried out by a one-grip harvester with timber extracted by a forwarder. The pilot works were carried out in June 2001 by sanitary felling of pine culture (Krpan and Poršinsky 2001, Krpan and Poršinsky 2002a) and in September 2002 by clear cut of fast growing deciduous species, i.e. thinning of natural stands of hard broadleaved trees (Krpan and Poršinsky 2002b). Despite the acquired experience and favourable research results (Krpan and Poršinsky 2004a, Krpan and Poršinsky 2004b, Krpan et al. 2004, Poršinsky et al. 2004), the introduction of a harvester-forwarder system, which represents today's top technology of forest harvesting, remained in Croatia at the level of experiments. It should be pointed out, however, that the present organisation of »Hrvatske šume« d.o.o. enables the use of a certain number of such high technology machines in Croatian forestry.

Most of felling and processing in »Hrvatske šume« d.o.o. is carried out by their own workers, about one fifth is carried out by contractors and a part is carried out by local inhabitants. The latter mostly refers to forest wood residues and wood from the so-called cleaning of stands, which has no technical value and it is usually self-processed for energy needs (Fig. 15).

3.2 Timber extraction – *Privlačenje drva*

Timber is extracted in two significantly different ways: ground skidding and timber forwarding, with

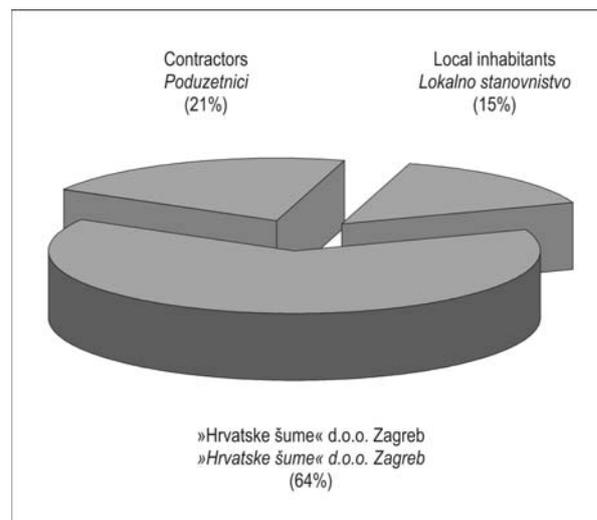


Fig. 15 Wood felling and processing by service providers in 2006 (forests managed by »Hrvatske šume« d.o.o.)

Slika 15. *Sječa i izradba drva prema izvršiteljima u 2006. godini (šume kojima gospodare »Hrvatske šume« d.o.o.)*

which the method of felling and processing is closely connected.

According to the above basic methods of extraction, which depend on stand and terrain conditions and partly on the so-called technical heritage, about more than half of the allowable cut in the Croatian state forests is skidded /forwarded by the machinery of the company »Hrvatske šume« d.o.o. and the rest is by third-party contractors (Fig. 16).

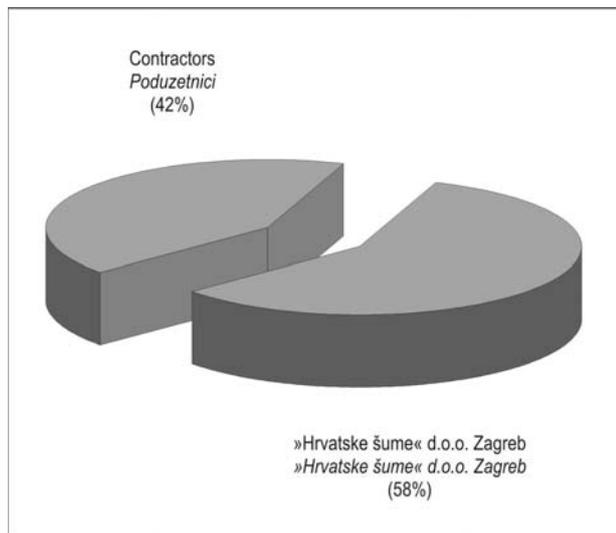


Fig. 16 Wood skidding/forwarding by service providers in 2006 (forests managed by »Hrvatske šume« d.o.o.)

Slika 16. Privlačenje drva prema izvršiteljima u 2006. godini (šume kojima gospodare »Hrvatske šume« d.o.o.)

Despite numerous disadvantages and low production level, a considerably large number of farm tractors adapted for forest work have still been retained by the company »Hrvatske šume« d.o.o., primarily due to quite a large quantity of industrial timber and wood for chemical processing obtained after thinning (thinning accounts for 35% of the total allowable cut). More than a fifth of the total quantity of timber extracted by »own forces« is carried out with these machines (Fig. 17 and 18, Table 1). These figures show that almost three fifths of the total quantity of processed timber is skidded by skidders and less than a fifth is forwarded by forwarders.

Figures 17 and 18 show a great difference in productivity between adapted farm tractors and skidders: almost three fifths of processed timber is skidded by 270 skidders, while at the same time only somewhat more than one fifth is extracted by 280 adapted farm tractors. It should be noted, however, that most of the time approximately one third of farm tractors are also engaged in forest silvicultural works.

Table 1 The average efficiency of wood skidding/forwarding for the period 2002–2006¹

Tablica 1. Prosječno ostvarenje privlačenja drva za razdoblje 2002–2006.¹

Type of vehicle Vrsta vozila	Average number of vehicles, pos. Prosječan broj vozila, kom.	Average annual productivity, m ³ Prosječan godišnji učinak, m ³	Average annual productivity of vehicle, m ³ /year Prosječan godišnji učinak po vozilu, m ³ /god.	Average daily output of vehicle, m ³ /day Prosječan dnevni učinak po vozilu, m ³ /dan	Average annual operating hours, h/year Prosječno godišnje ostvareni radni sati po vozilu, h/god.	Average annual days per vehicle, day/year Prosječno godišnje ostvareni radni dani po sredstvu, dan/god.	Utilisation, % Iskorištenost, %	Availability, % Ispravnost, %
Farm tractors >1,5 t Farm traktori >1,5 t	282	376 345	1333	9	1131	141	56	80
Skidders <5t Skideri <5t	103	231 471	2238	14	1317	165	65	83
Skidders >5t Skideri >5t	168	782 438	4666	27	1391	174	68	86
Forwarders Forvarderi	25	327 936	13117	70	1506	188	62	80
Total Ukupno	579	1 718 190	2970	19	1256	157	61	82

¹ Data from the software used by »Hrvatske šume« d.o.o. – Monitoring of expenses and efficiencies of production machines, which represents a monthly report of machine work. Data are entered at the level of forest offices, work units and forest administrations, individually for each machine and are summed up at the level of the company »Hrvatske šume« d.o.o. where they are processed into a final report. – Podaci iz programske aplikacije »Hrvatskih šuma« d.o.o. – Praćenje troškova i učinaka strojeva u proizvodnji koja predstavlja mjesečno izvoštavanje o radu strojeva. Podaci se unose na razini šumarija, radnih jedinica i u uprava šuma podružnica, pojedinačno za svako sredstvo te se zbrajaju za razinu trgovačkog društva »Hrvatske šume« d.o.o. gdje se obrađuju kroz željeni izlazni izvoštajni oblik.

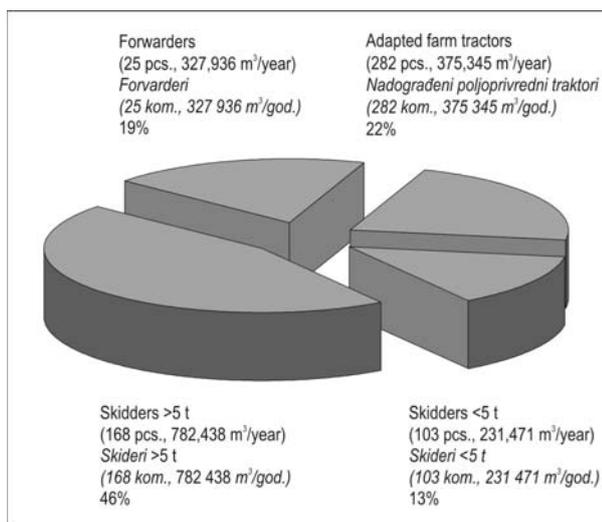


Fig. 17 Average shares and quantities of wood extracted by the machinery of »Hrvatske šume« d.o.o. in the period 2002–2006 by vehicle type

Slika 17. Prosječni udjeli i količine privučenoga drva vlastitim sredstvima »Hrvatskih šuma« d.o.o. u razdoblju 2002 – 2006. prema vrsti vozila

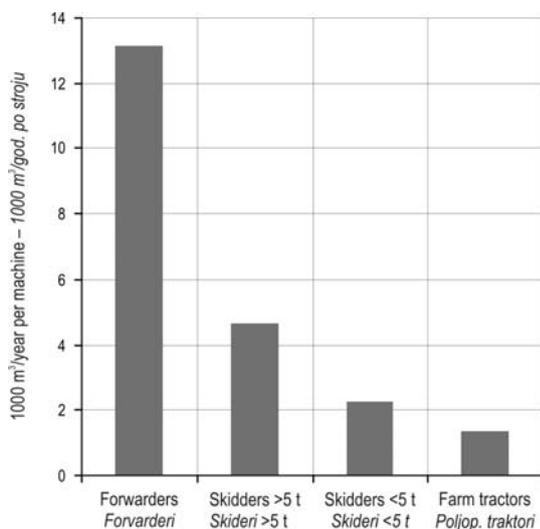


Fig. 18 Average annual productivity of vehicles for timber extraction (»Hrvatske šume« d.o.o., period 2002–2006)

Slika 18. Prosječna ostvarena godišnja proizvodnost sredstava za privlačenje drva (»Hrvatske šume« d.o.o., razdoblje 2002 - 2006)

The productivity of forwarders is several times higher than the productivity of all machinery used for timber skidding (Fig. 18).

3.3 Wood transportation – Prijevoz drva

It can be seen from Figure 19 that almost four fifths of wood felled in the state forests of the Republic of Croatia are transported by private contractors

and only one fifth is transported by trucks owned by »Hrvatske šume« d.o.o. This is partly the result of wood selling policy, which enables buyers to transport wood by their own trucks, but also the result of the general situation in the market of these services. The part of wood transport carried out by the capacities of »Hrvatske šume« d.o.o. consists of up-to-date means of transport and loading machines which do not lag behind the European or world trends and technologies (Tomašić *et al.* 2005).

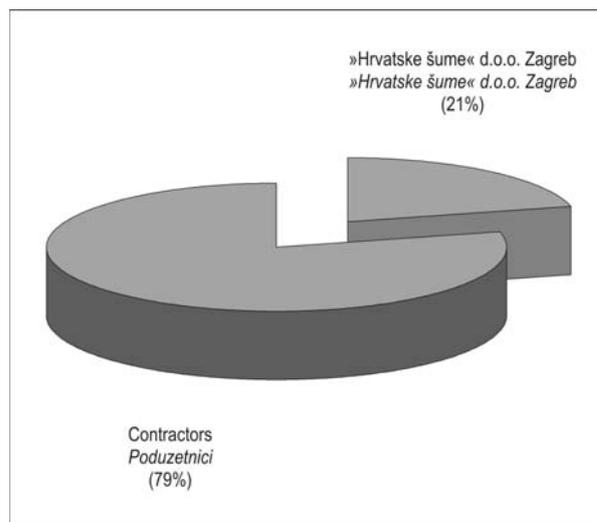


Fig. 19 Wood transportation by service providers in 2006 (forests managed by »Hrvatske šume« d.o.o.)

Slika 19. Prijevoz drva prema izvršiteljima u 2006. godini (šume kojima gospodare »Hrvatske šume« d.o.o.)

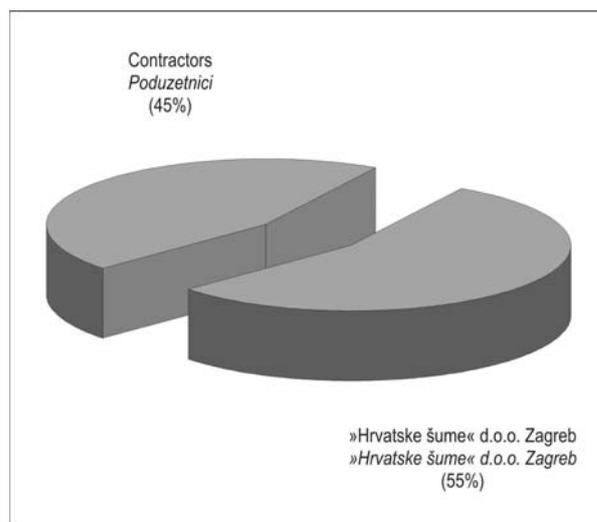


Fig. 20 Building of forest roads by service providers in 2006 (forests managed by »Hrvatske šume« d.o.o.)

Slika 20. Izgradnja šumskih prometnica prema izvršiteljima u 2006. godini (šume kojima gospodare »Hrvatske šume« d.o.o.)

3.4 Building of forest roads – *Izgradnja šumskih prometnica*

In 2005 the total length of forest roads in forests managed by »Hrvatske šume« d.o.o. was 15.5 thousand km, which ensured total openness of about 7.8 m/ha. Figure 20 shows that in 2006 about 55% of the value of all jobs related to designing and building of forest roads was performed by capacities of »Hrvatske šume« d.o.o., while 45% of these services were provided by contractors.

4. The influence of »Hrvatske šume« d.o.o. on the development of mechanisation of procedures and technologies, and harmonisation of development trends with management purposes – *Utjecaj »Hrvatskih šuma« d.o.o. na razvoj mehaniziranosti tehnologija i tehničkih sredstava i usmjeravanje razvojnih tokova u skladu s ciljevima gospodarenja*

»Hrvatske šume« d.o.o. influence the formation and development of procedures and technologies in state forest management, which can be seen in several basic requirements:

- ⇒ Environmental suitability of applied procedures and technologies
- ⇒ Efficiency in compliance with working conditions
- ⇒ Meeting safety requirements of use of machines and technologies
- ⇒ Ergonomic suitability of machines.

Within the scientific-research programme financed by »Hrvatske šume« d.o.o., the very choice of the research subject speaks for itself about the significant interest in projects which include research topics related to the above requirements. Proposals for research topics have mostly come as a result of practice, but they have also been defined by development and production services of the Company, and namely:

- ⇒ Technologies of ground wood skidding
- ⇒ Ecologically acceptable technologies in forest management according to applicable international standards
- ⇒ Machine methods of slash stacking after felling and processing
- ⇒ Ecologically acceptable forest techniques
- ⇒ Licensing and accreditation for achieving European standards of safety and quality of forest work
- ⇒ Ergonomic characteristics of forest machines and establishment of conditions of these machines.

4.1 Focus on development of environmentally acceptable forest machines and technologies – *Naglašena okrenutost razvoju ekološki prihvatljivih šumarskih strojeva i tehnologija*

The awareness of the comprehensive meaning of development, introduction, implementation and upgrading of such procedures and technologies, based on ecological acceptability, prevails as one of the basic aims of the profession upon which most of other aims depend and without which they could never be achieved. Therefore, much attention was focused on preventing adverse effects and/or decrease of adverse effects caused by the implementation of certain procedures and use of certain machines in forest management.

Environmentally harmful effects caused by work of forest machinery can be mechanical and chemical. The research of environmental suitability of implemented methods and technologies, focused on mechanical damage to forest soil, involve the determination of soil compaction by wheels and skidded load performed by measuring changes of physical-mechanical soil characteristics (penetrating and shear resistance, changes of moisture content and pore volumes, determining wheel numeric, etc.). Mechanical and chemical damaging influence of machine work can cause significant damage to standing trees and other plants, as well as to animal world and its habitats. Therefore, such a damaging effect is also investigated. Attention is focused on studying harmful chemical changes in soil, also related to machine operations, by which biological soil function is jeopardised, as depository of food for the existing and future forest vegetation and irreplaceable storage and source of drinking water. Emission of hazardous gases, condensates and liquified harmful substances into environment and atmosphere should also be mentioned as harmful chemical effects of machine operations.

One of such researches refers to comparative research of the biological-chemical influence of mineral and biodegradable lubricants spilled on the ground by use of chain saws and skidders/forwarders. It particularly refers to systematic spillage of large quantities of oil for lubricating saw chains into forest soil, as all felling and processing of the allowable cut is carried out by chainsaws. It is known from previous research that the unit consumption of oil for lubricating chain saws is between 0.11 and 0.15 L/m³. Taking into account the lowest unit consumption, according to the average net annual allowable cut in »Hrvatske šume«, the result is that more than half a million litre of oil only used for lubricating of saw

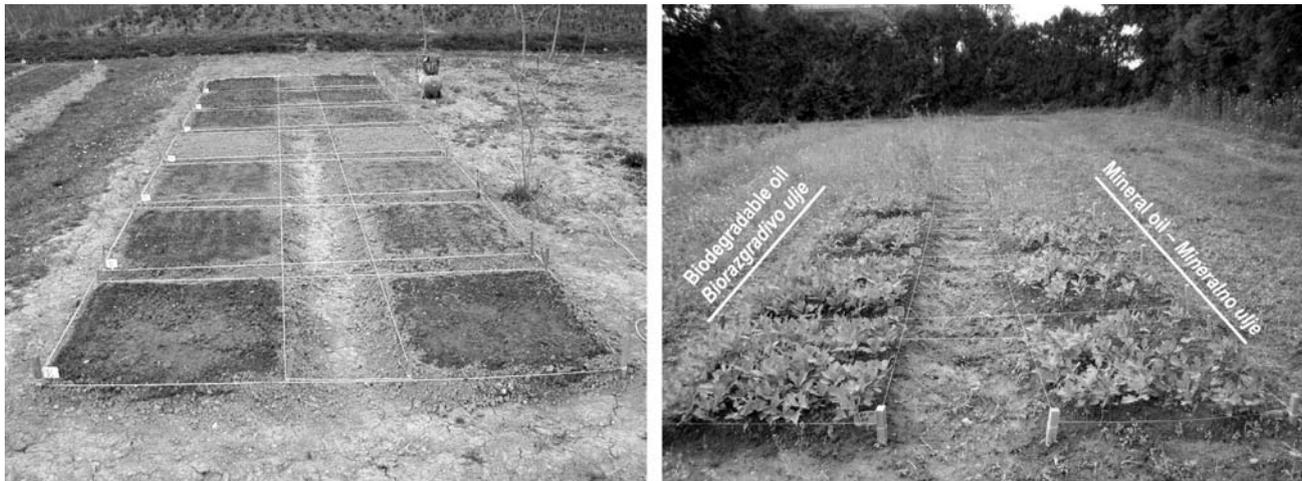


Fig. 21 Research of the effects of biodegradable and mineral lubricants in soil
Slika 21. Istraživanje posljedica djelovanja u tlu odlaganih biološki razgradivih i mineralnih maziva

chains is deposited into forest soil per year. Although a small quantity of lubricants remains in the processed wood and one part on the surrounding plants, still almost half a million litre of oil is spilled into the soil. If quantities are added of hydraulic oil spilled from hydraulic systems and systems of other machines (faults, carelessness), which cannot possibly be estimated, then it becomes clear what quantities are dealt with here. The fact should be kept in mind that by entering into soil mineral lubricants (which have a very poor degradability) jeopardise underground waters to such an extent that one litre of that lubricant can pollute thousand litres of underground water, but also make worthless about 1 million litre (Auguštin *et al.* 2000).

The research of the effects of biodegradable and mineral oils is carried out so that a certain area of forest soil covered with e.g. oak pedunculate acorn is watered by various concentrations of biodegradable or mineral lubricants mixed with water, and effects and results are recorded of the influence of such watering by the solution of both types of lubricants on planted seeds and young plants (germination, growth and increment of seedlings, etc). These researches are still under way and the results have not yet been determined (Fig. 21).

Apart from the research of the influence of lubricants on forest soil and its biological productivity, increasing interest has been recorded for the biological propulsive fuel used by forestry machines in the Republic of Croatia. Thus, in 2005 the first Croatian thinning skidder driven by bio-diesel was manufactured in Rijeka and all hydraulic oils are biodegradable (Sever and Puljak 2005).

4.2 Participation in the development of machines and technologies – *Sudjelovanje u razvoju strojeva i tehnologija*

4.2.1 Participation of »Hrvatske šume« d.o.o. and the Faculty of Forestry, University of Zagreb in the development of special forest machines – *Sudjelovanje »Hrvatskih šuma« d.o.o. i Šumarskoga fakulteta Sveučilišta u Zagrebu u razvoju posebnih šumarskih strojeva*

»Hrvatske šume« d.o.o. and forestry science (Faculty of Forestry, University of Zagreb) have a great influence on the development of mechanised vehicles as a result of the established cooperation with the Croatian manufacturers of forest machines, on which demands are imposed for fulfilling specific technical, safety, ergonomic and other conditions in designing machines. The way in which domestic middle thinning skidders – Ecotrac 55V and skidder Ecotrac 120V were developed is a good example of the participation of the employees of »Hrvatske šume« d.o.o. in the development of special forest machines. The first machine was intended for work in thinning on sloping terrains and first of all it had to meet morphological demands (width and length) in order to be able to move among standing trees in thinning stands and on the existing and considerably narrow strip roads. Further development of that machine included all demanding ergonomic and safety conditions.

Skidder Ecotrac 120V was developed completely in accordance with the demands of the employees of »Hrvatske šume« and in cooperation with the representatives of forest science with the financial support of the Ministry of Science of the Republic of

Croatia (Horvat 2004). Before the beginning of the realisation of this developmental project, a comprehensive survey was carried out of the opinion of operators of similar machines already engaged in timber skidding under given conditions, mechanics experienced in maintenance of similar machines and foremen about the observed disadvantages and advantages of machines, which had been performing similar jobs under similar terrain and working conditions. After having collected their comments, suggestions and opinions, the answers were classified and the review of advantages and disadvantages of the existing machines was made, based on which technical-technological demands were imposed on the manufacturer. They can be reduced to four basic demands, already mentioned above: environmental suitability, productivity, safety and ergonomic features.

The first demand of technical suitability in terms of environmental protection is primarily related to the width of strip roads which is between 2.5 and 3 m in forests managed by »Hrvatske šume« d.o.o. (Pičman and Pentek 2003). Also attention had to be paid to the machine height and length (axle base) due to low branches and limiting vertical and horizontal curves of the existing strip roads. Since at the same time there were many comments claiming that the mass of some of the existing skidders (9–10 t) was too high in relation to the soil bearing capacity of these areas, the mass of the future skidder was not to exceed 7 t. This is why this skidder was also called »skidder of about 7 t mass« in the period before a prototype was made.

Based on morphological analysis (dependence of width, height and length on mass) of families of skidders and middle skidders, the positions of skidders developed in Croatia: a thinning skidder Ecotrac 55V and skidder Ecotrac 120V are shown in Figures 22, 23 and 24. It can be seen from the figures that all demands related to the dependence between skidder size and mass are met and can be considered favourable. There is a particularly favourable relation between the skidders width and mass (Fig. 22), where widths are noticeably below equalisation curves, which is the result of the above mentioned harmonisation between demands of forestry profession and design solutions.

These figures also show that the skidder length and height are above the equalisation curve. According to the ISO standard definition, larger length than the average value of other skidders is caused by the installation of the front thrust blade operated by two long stroke hydraulic cylinders, by which quite a big movement curve is enabled, as well as by the rear anchoring blade. The above average skidder

height in relation to mass (position of the point above the equalisation curve) also arises out of the definition of the same standard according to which the total height is defined as the distance from the ground to the highest skidder's point. With these skidders it refers to the edge of the exhaust pipe placed above the cabin roof in order to meet safety demands of ISO standard to prevent the entrance of exhaust gases into the skidder cabin through a ventilation

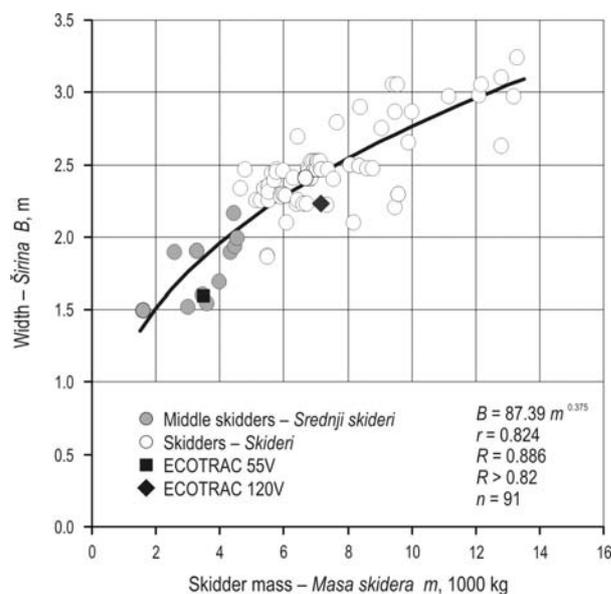


Fig. 22 Relation between skidder mass and width
Slika 22. Odnos mase i širine skidera

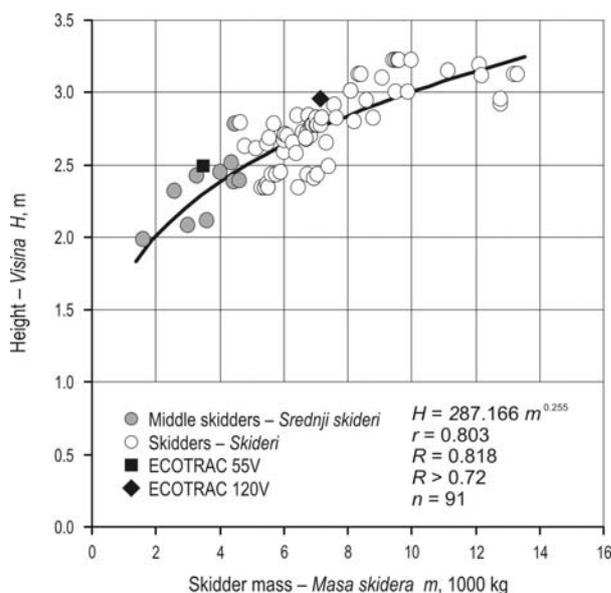


Fig. 23 Relation between skidder mass and height
Slika 23. Odnos mase i visine skidera

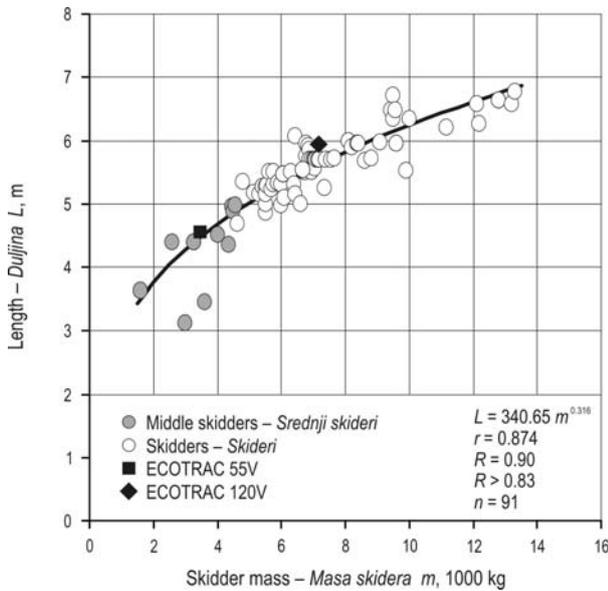


Fig. 24 Relation between skidder mass and length
Slika 24. Odnos mase i duljine skidera

opening. Therefore, the total height of the domestic skidder is higher than average values of other skidders listed in database, out of which a large number had been manufactured before the above ISO standards had been issued.

The above mentioned database, which was used for the morphological analysis, refers to the database compiled by Sever and Horvat (1985, 1992a, 1992b), Horvat (1996c, 1996d), and later supplemented by data from databases for some features of forest ma-

chines of the Department of Forest Techniques of the Forestry Research Institute of the Austrian Ministry of Agriculture and Forestry (FBVA 2000, FBVA 2003). This database contains a total of 91 types of skidders.

The position of the form index of domestic skidders (B/L), which, according to Bekker (1956) defines the penetrability of a vehicle in relation to other machines within the skidder family, is also outside the set demands of the forest practice. As already explained above, the immediate aim for meeting these demands of small machine width was the result of exceptionally narrow strip roads, in most cases not exceeding 2.5 m, and of the use of smaller skidders in thinning operations. Hence, the relations between the width and length are on the very edge of the skidder family and these machines are characterised by a particularly suitable small width in relation to length (Fig. 25).

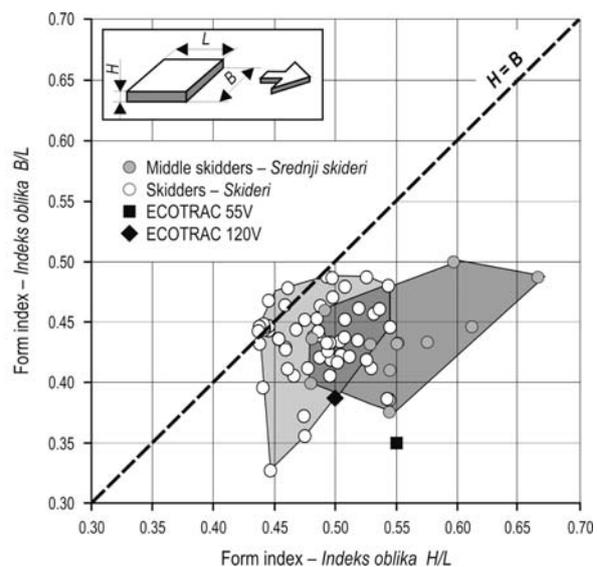
A domestic skidder Silva S101, ten of which were produced in the 1980s in the then Forest Administration of Vrbovsko, was used as an example of a part of technical and dimensional features of skidders. It primarily refers to dimensioning of axles which, after more than two decades of use, proved to be very favourable. Even today four of these machines are used for timber skidding in selective forest conditions.

The demand for ensuring productivity was expressed in requiring increased engine power in relation to the average power of the skidder group, by which higher skidding speeds were ensured in hilly and particularly in mountainous stands.

The third out of four key demands imposed on the manufacturer of the domestic skidder by the



Fig. 25 Skidder form index
Slika 25. Indeksi oblika skidera



science and profession, which according to its significance could have been placed first, referred to the safety of the working machine. Among thirty demands specified by ISO Standard (Horvat and Šušnjar 2003), which refer to safety issues and some ergonomic features, the following represent the most important research areas of safety-ergonomic features:

- ⇒ Technical safety devices
- ⇒ Accessing devices
- ⇒ Cabin design (cabin protection, cabin space, seat, zone of comfort and access to control commands)
- ⇒ Light devices
- ⇒ Steering (proper function of the steering system, control commands forces, symbols of control commands)
- ⇒ Safety demands for winch design and operation.

The most demanding conditions for confirming the machine safety refer to the skidder cabin. Apart from some other ISO standard demands, it refers particularly to the existence of ROPS (*Roll-Over Protective Structure*), FOPS (*Falling Object Protective Structure*) and OPS (*Operative Protective Structure*). All the demanded conditions were met, including the most demanding cabin tests, which were performed abroad.

The most important ergonomic demands for skidders definitely refer to the decrease of harmful effects of noise and vibrations. Some researches of the Institute for Health Protection of the Republic of Croatia showed that noise and vibration have been

the most significant causes of professional diseases in relation to other conditions (Fig. 26) and forestry is ranked second in the number of disabled persons as a result of professional diseases (Horvat and Sever 1997).

Measurement of noise level in the skidder cabin, with the so-called silent cabin and modern engine installed, showed that skidders meet all safety-at-work requirements in accordance with the prescribed limit values for noise over an eight hour exposure. Such a level of noise enables free communication at the workplace, provides conditions for reducing injuries at work and for improving total satisfaction of drivers and increasing productivity. All other measuring points showed that the noise level emitted by a skidder was not above the limit values.

The noise was measured (Horvat *et al.* 2004a, Horvat *et al.* 2004b):

- ⇒ in a skidder cabin next to the driver’s ear in accordance with ISO 5131:1996 and ISO 6394:1998
- ⇒ in the vicinity of the skidder in accordance with ISO 4872:1978 and ISO 6393:1998
- ⇒ in the vicinity of the skidder during acceleration in accordance with ISO 362:1998
- ⇒ and it met all requirements prescribed by these standards.

Vibrations were measured at two measuring points crucial for determining vibrations risks: on the steering wheel and on the seat. For measuring vibrations on the steering wheel, standards were used for vibrations transferred via fist or from the seat to the whole body and namely HRN ISO 5349:2001 EN and HRN ISO 5349:2001 EN. The results showed that vibrations on the steering wheel were well damped with the exception of vibrations at idling. In other words, it means that signs of permanent consequences could only appear with 10% of drivers exposed to measured vibration levels for a comparatively long time, assuming that during a full-time working day engine is kept at the lowest number of revolutions. The conclusion on vibrations transferred from the wheel to hands shows that the examined skidders are ergonomically fit means of work.

Vibrations were measured on the seat in accordance with the standard HRN ISO 2361-1:1997 EN. The measurement results showed that vibrations transferred from the seat to the driver’s body are not a limiting factor. Damping features of seats were well chosen. The driver can spend more than eight hours, the duration of a shift, without any consequences under established conditions.

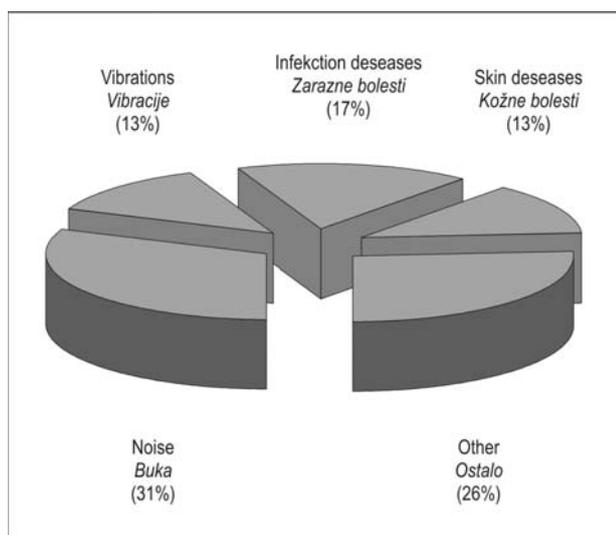


Fig. 26 Distribution of causes of professional diseases
Slika 26. Razdioba uzroka profesionalnih bolesti

4.2.2 Participation of »Hrvatske šume« d.o.o. and Faculty of Forestry, University of Zagreb in the development of forestry technologies – *Sudjelovanje »Hrvatskih šuma« d.o.o. i Šumarskoga fakulteta Sveučilišta u Zagrebu u razvoju šumarskih tehnologija*

The following example refers to the direct participation of »Hrvatske šume« d.o.o. and forestry science in planning, development and upgrading of original technologies related to conditions in the Croatian forestry.

Determination and selection of suitable procedures for thinning operations are among the most significant management issues in naturally regenerated forests of pedunculate oak in the eastern parts of Croatia. According to the tree value (pedunculate oak), these forests are considered the most valuable forests in the Republic of Croatia. However, since these lowland forest stands of oak and ash trees developed on deep pseudogleic soil of a very low bearing capacity and high water content in the soil, there are numerous difficulties related to forest harvesting. They primarily refer to further mechanisation of these works and choice of the most favourable method for extracting timber from the stand after felling. Apart from the above problems related to poor bearing capacity of the soil, the same difficulty is encountered in biological features of the main tree species and the most important commercial species – pedunculate oak, which is also the most sensitive species in the early age of seedlings and offspring. The natural regeneration of pedunculate oak forests is a very complex and expensive procedure, even in case when it is performed properly, professionally and without any mistakes, and it requires a long-term investment and great efforts.

Further to the above, in thinnings of these stands it is very important to preserve a sensitive forest soil that has to perform its feeding, productive and supporting task for a long time. Since it is known from many scientific researches, as well as from experience, that much less damage to the soil is caused if timber is forwarded from the forest after felling than when it is skidded, forwarding was promptly chosen. However, this procedure was not considered final, and efforts are being made to find a procedure that would prevent threading of the whole felling site while bunching timber from one stump to another, and provide the possibility of bunching timber exclusively by use of skid trails, without entering into the stand. In this way protection would not only be provided to forest soil but also to standing trees and seedlings in a forest stand. In order to remove cut timber by access tracks, parallel unstocked strips were first made within forest stands at the distance of 75 m, the so-called »strip paths« 3 m wide and

lately (in newly regenerated stands) these distances were halved and now such paths are made for the same purpose at every 36 m. Their basic role is to ensure free travel of machines and space from which wood is winched and/or loader bunched and then transported to the (roadside) landing.

The next thing that has to be taken into account when choosing the right machine, as an important component of the chosen procedure for these conditions, is the fact that timber assortments from thinning are of smaller dimensions and lower quality and make about 35% of the total annual allowable cut. Therefore, the problem of wood removal from the lowland forest thinnings are not only of ecological, but also of economic nature, since the use of considerably expensive machines for this purpose would create working costs that can hardly be covered by wood itself.

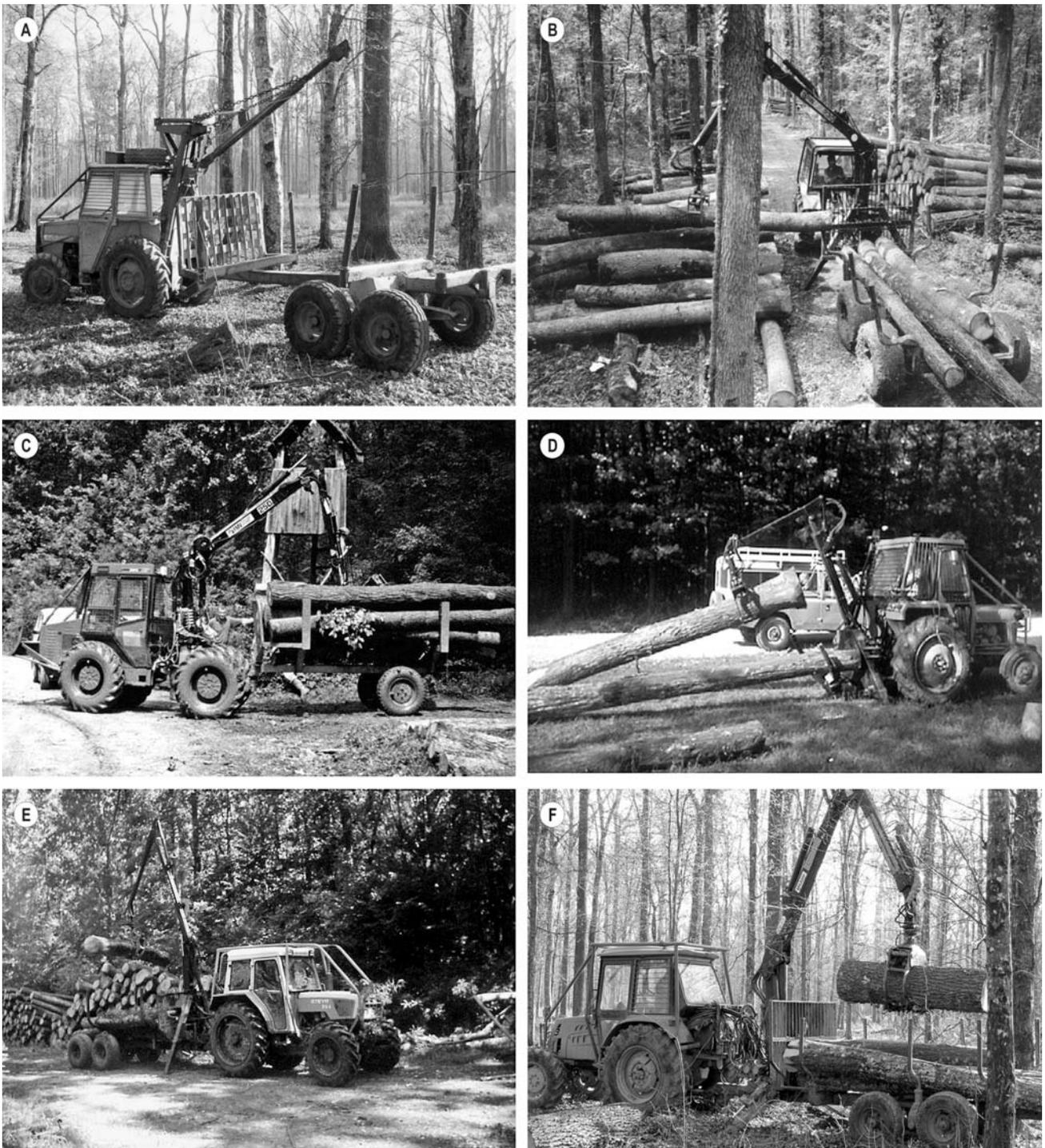
The extraction of timber after thinning in these areas started in early 1970s by use of first tractor assemblies, which consisted of a farm tractor, forest semi-trailer, mechanised console loader and forest winch. The first such tractor assembly was called »Pionir«. Unlike the above mentioned efforts to avoid the entrance of tractors into the stand for timber extraction, »Pionir« assemblies travel across the stand bunching the processed timber and in doing so mostly cause damage to forest soil, seedlings and remaining trees.

By making additional parallel strip paths at distances half less than the existing ones (36 m), and thus increasing the forest openness, further progress was made in the described methods of timber extraction in lowland thinnings.

In the next period, development and improvement of equipping tractor assemblies continued by more up-to-date hydraulic loaders and forest winches. The activities related to looking for the most favourable solution of the tractor assembly were particularly increased in early 1990s. The next solution included the parallel work of the tractor assembly and adapted farm tractor equipped by a loader and grapple which collected processed timber assortments in the stand and skidded them to the strip path. From the point of view of ecological acceptability and particularly economic feasibility (two machines for the same work and much time spent in loading and unloading, unsuitable mechanised loader), the work organised in this way could not last long (Horvat *et al.* 2004).

In the chronological order the following types of machines, i.e. tractor assemblies were used in these areas for timber extracting:

- ⇒ »Pionir« assembly (Fig. 27A): farm tractor, forest semi-trailer, mechanised console loader with winch (in early 1970s)



Remark – Kazalo:

A) »Pionir« assembly – ekipaža Pionir

B) »FMV« assembly – ekipaža FMV

C) Thinning skidder with loader – *proredni skider s dizalicom*

D) Adapted farm tractor with loader and grapple – *nadograđeni poljoprivredni traktor s dizalicom i hvatalom*

E) »Steyr« assembly – ekipaža Steyr

F) »Formet« assembly – ekipaža Formet

Fig. 27 Various approaches to solving timber skidding from the lowland forest thinning

Slika 27. *Različiti pristupi rješavanju privlačenja drva iz proreda nizinskih šuma*

- ⇒ FMV assembly (Fig. 27B): farm tractor Torpedo 55A, semi-trailer Moheda 6 t with a hydraulic loader FMV 230 and hydraulic winch on the loader (1993)
- ⇒ thinning skidder with a semi-trailer and hydraulic loader without winch (Fig. 27C), (1996)
- ⇒ adapted farm tractor with a loader and grapple (Fig. 27D), in combination with the tractor assembly
- ⇒ »Steyr« assembly (Fig. 27E): farm tractor Steyr 860, semi-trailer Kronos 6 t and hydraulic loader Kronos 250 with a hydraulic winch on the loader (1997)
- ⇒ »Formet« assembly (Fig. 27F): tractor Steyr 8090 (or any other farm tractor of such power and other appropriate features), a double drum winch Igland 6002 Pronto TL of the rated tractive force of 60 kN, hydraulic loader Igland 43–65 and semi-trailer Metalac S-6, of the carrying capacity of 6 t (2004).

It should be mentioned that the work in finding the most favourable approach to timber skidding after thinning is not even close to its completion. The basic problem is to balance several features of the most favourable technological-technical solution, which would meet the requirements of environmental acceptability, safety-ergonomic features and economic feasibility supported by satisfying productivity. Although this sounds utopian, a lot can be achieved in this area by a persistent systematic work on improving each of the above factors individually and with the help of knowledge and science in general.

5. Conclusions – Zaključci

Since more than 96% of the total area covered by forests and managed by Hrvatske šume d.o.o. is of natural structure, specific management of these forests demands original solutions and methods which have to meet set criteria for:

- ⇒ environmental suitability
- ⇒ efficiency
- ⇒ safety
- ⇒ ergonomic features.

Here, special emphasis is placed on the requirements of ecologically acceptable machines and procedures in forest management, as well as on the possibility of decreasing their unfavourable mechanical and chemical influence on soil and conditions within forest ecosystems in general.

»Hrvatske šume« d.o.o. carry out more than 50% of activities related to forest management by their

own production capacities, except wood transportation. Therefore, the fulfilment of the above requirements is the objective of scientific-research projects financed by »Hrvatske šume« d.o.o., whose experts take active part in the development of the most frequently used machines and methods of timber skidding, like thinning skidder, skidder and technical-technological solutions for lowland forest thinning.

While it can be generally said that skidders meet the required conditions, the most favourable variant is still sought for the technical solution of thinning machines in the lowland forests of the Republic of Croatia, since previous solutions failed to meet all the required criteria, particularly not the part related to productivity, as wood from these fellings is of lower technical and economic value.

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Sažetak

Stanje i razvoj mehaniziranosti pridobivanja drva u hrvatskom državnom šumarstvu

U radu se opisuje ovođobno stanje gospodarenja šumama u Republici Hrvatskoj, s posebnim osvrtom na šume kojima gospodari trgovačko društvo »Hrvatske šume« d.o.o. Zagreb, na ciljeve, zadatke i način gospodarenja šumama u državnom vlasništvu, na stanje i dosadašnje kretanje broja najznačajnijih mehaniziranih sredstava pridobivanja drva. Također se opisuje način te aktivnosti kojima »Hrvatske šume« d.o.o., u suradnji sa Šumarskim fakultetom Sveučilišta u Zagrebu, utječu na smjer razvoja strojeva i postupaka u pridobivanju drva kao izvornih rješenja za posebno zahtjevne uvjete prirodna načina gospodarenja šumama.

Od ukupne površine šuma i šumskoga zemljišta u Republici Hrvatskoj u državnom je vlasništvu 75 % ploštine, odnosno 2 018 987 ha kojima gospodare »Hrvatske šume« d.o.o. Preko 50 % radova u gospodarenju »Hrvatske šume« d.o.o. izvode vlastitim proizvodnim snagama i sredstvima. Stoga je razvoj strojeva i postupaka vrlo bitan preduvjet poboljšanja poslovne uspješnosti u složenim terenskim prilikama, posebno obilježenim posebnostima načina gospodarenja. Pri tome se mogu izdvojiti četiri glavna mjerila u zahtjevima pogodnosti, odnosno prikladnosti tehničko-tehnoloških rješenja:

- ⇒ okolišna pogodnost
- ⇒ djelotvornost
- ⇒ sigurnost
- ⇒ ergonomska pogodnost.

Ta su mjerila djelomice oblikovana poznatom propisanošću suvremenih međunarodnih normi, primjenjivih za uvjete u Republici Hrvatskoj, a djelomice i samom posebnosti uvjeta gospodarenja. Utjecaj »Hrvatskih šuma« na zadovoljavanje navedenih zahtjeva te izravno sudjelovanje u razvoju prikladnih tehničko-tehnoloških rješenja za određene uvjete prikazani su na primjerima razvoja dvoiju vrsta skidera i traktorskih ekipaža za prorode nizinskih šuma. Ti se zahtjevi ispunjavaju preko zadataka znanstvenoistraživačkih projekata i suradnje sa Šumarskim fakultetom Sveučilišta u Zagrebu te postavljanjem zahtjeva i suradnjom s domaćim proizvođačima strojeva i opreme.

Ključne riječi: Hrvatske šume d.o.o., prirodne šume, razvoj strojeva i tehnologija, skideri, traktorske ekipaže

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