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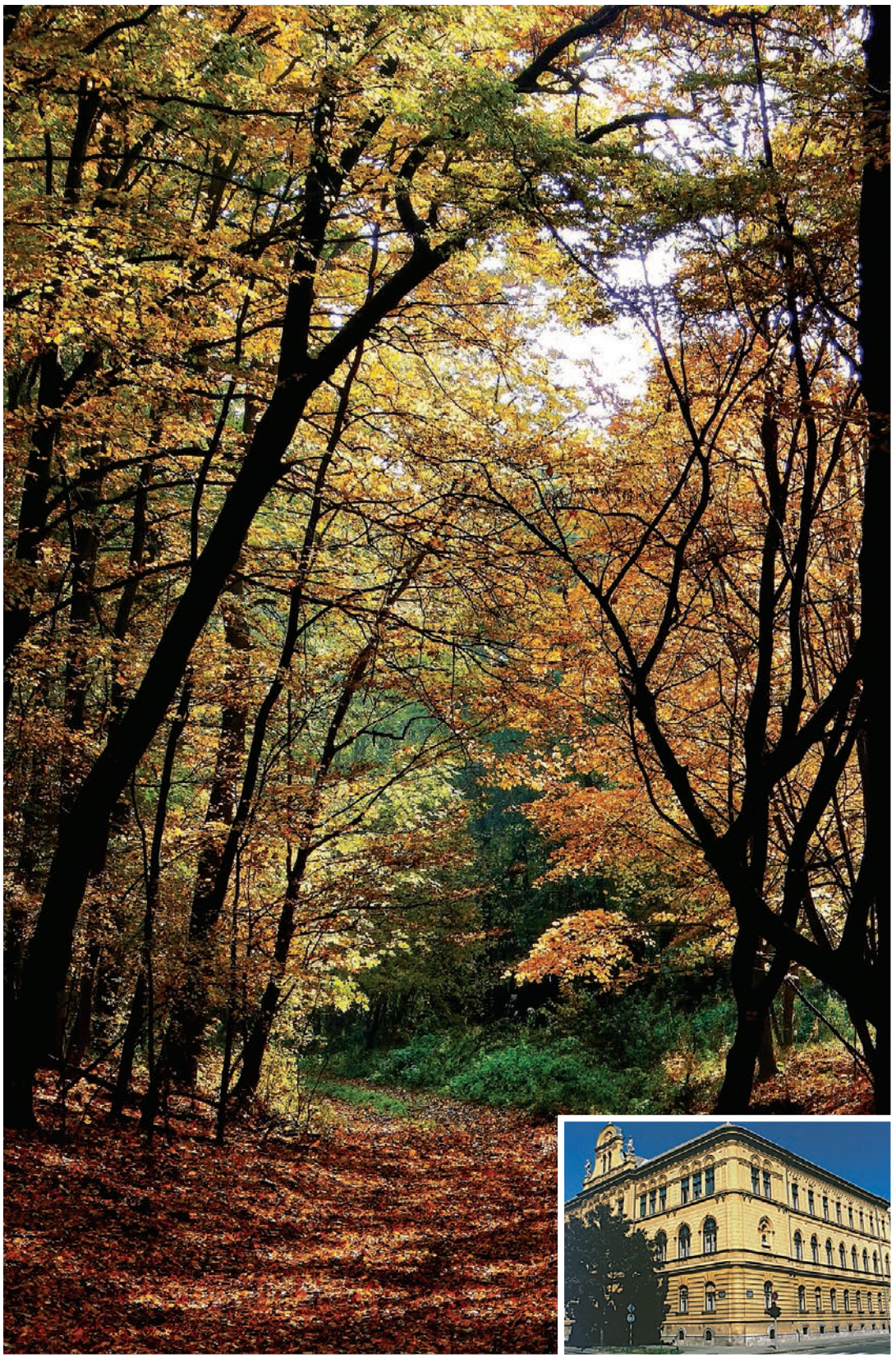

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2022

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„Šumski put" – fotografija Bjelovarskog salona fotografija „Šuma okom šumara" (Foto: Peter Farkaš)
Weg im wald („Forest puth") – a photograph of the Bjelovar Photography Salon „The Forest Through the Eyes of a Forester" (Photo: Peter Farkaš)

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Na osnovi mišljenja Ministarstva znanosti, obrazovanja i športa Republike Hrvatske, „Šumarski list" smatra se znanstvenim časopisom.

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In memoriam

RIJEČ UREDNIŠTVA

ŠUME U SLUŽBI DECENTRALIZACIJE I DEMOGRAFSKOG OPORAVKA HRVATSKE

Posljednje desetljeće, posebice unazad nekoliko godina, šumarska struka izražava bojazan za stanje šumskih ekosustava i najvrjednijih vrsta drveća, jer nema vrste koja nije pod pritiskom starih, posebno novih štetnika i bolesti, koji u sinergiji s klimatskim promjenama značajno smanjuju njihovu vitalnost. Tako je vrsta poljski jasen, značajna sastavnica nizinskih šumskih sastojina, već dostigla kritičnu fazu u svom odumiranju. I mi smo se u našim uvodnicima osvrtali na navedeno, ukazivali na važnost i značaj svih poteza na globalnoj i državnoj razini koji idu u smjeru brige za veliko šumsko bogatstvo koje Republika Hrvatska posjeduje. Hrvatski mediji u recentnom vremenu bavili su se objavljenim rezultatima popisa stanovništva provedenog 2021. godine. Time su u interes javnosti opet došli demografi, koji istu priču ponavljaju desetljećima, no nositelji odluka ih ne slušaju. Mogli bi povući paralelu i s našom desetljetnom pričom o nazivu resornog ministarstva, a posebice uloge koje to ministarstvo ima prema šumi, resursu koje pokriva skoro polovicu države. Zanimljivo je da su i demografi uočili ulogu javnog šumoposjednika Hrvatskih šuma koje gospodare državnim šumama na čitavom državnom području. Njihov prijedlog je decentralizacija: „Danas Hrvatske šume gospodare čitavim prostorom u Hrvatskoj, to je uvjetno rečeno centralizirano. To treba zaista prepustiti lokalnim zajednicama da one snose odgovornost, ali i da imaju isto tako ovlasti.“ Primjerice, Gorski kotar kraj koji je preko 70 % prekriven šumom, u sedamdesetim i osamdesetim godinama 20. stoljeća, kada je šumarstvo bilo u funkciji razvoja lokalne zajednice, razvijao se i podizao životni standard ljudi i kraja. Danas je to kraj izložen depopulaciji, a šumski potencijali kojima raspolaže nisu iskorišteni, ili se troše negdje drugdje. Slična priča odnosi se i na Slavoniju koja posjeduje ekonomski najvrjednije šume, ali koje dodanu vrijednost stvaraju dalje od mjesta gdje rastu. Iz ove bogate regije bilježi se u posljednje vrijeme i najveće iseljavanje.

Može li se preokrenuti opisani trend? Prilikom donošenja strateških planova i njihovih provođenja trebalo bi se više bazirati na komparativnim prednostima određenog kraja. Smatramo da usmjerenost samo na gospodarenje sirovinom bez gospodarenja prostorom i bez strateškog zapošljavanja kadrova, dovodi ruralne prostore Hrvatske u još nepovoljniji položaj te vodi sve većem pražnjenju tog istog prostora. Ekonomske politike koje pogoduju uskim interesnim skupinama već su uzele svoj danak. Poticaji iz Europskih fondova, koji su dosta izdašni, motiviraju korisnike na instant bavljenje određenom djelatnošću, a krajnji cilj povećanje proizvodnje obično nije ispunjen. Često i korisnici sredstava iz fondova ne obitavaju u području za koje su sredstva namijenjena. Zakonom o šumama i Zakonom o poljoprivrednom zemljištu predviđeno je razgraničenje šumskog i poljoprivrednog zemljišta prema stanju u naravi i usklađivanje s katastrom, čijom bi se provedbom olakšalo gospodarenje šumama i uklonilo probleme koje su nastali zakupima velikih površina za pašarenje, čiji su rezultati jako upitni. Nažalost, ovaj jako bitan preduvjet za kvalitetnije gospodarenje prostorom i zadržavanje, ali i povećavanje broja stanovnika u njemu, nije ispunjen. Kao i u drugim segmentima, godine prolaze bez provedbe zakona i strategije glede zacrtanih ciljeva. Organizacija šumarstva u nekim susjednim državama možda nudi odgovore na naša pitanja. Austrijske i mađarske šumarske tvrtke ne bave se samo proizvodnjom i prodajom drvnih sortimenata, već su im djelatnosti vezane i za obnovljive izvore energije i zaštitu prirode, čime se proširuje mogućnost zapošljavanja lokalnog stanovništva. Na kraju i njihovi šumari imaju bolja primanja i standard.

Uredništvo

EDITORIAL

FORESTS IN THE SERVICE OF DECENTRALISATION AND DEMOGRAPHIC RECOVERY OF CROATIA

In the last decade, and especially in the past several years, the forestry profession has expressed concern for the state of forest ecosystems and the most valuable tree species. Namely, there is no species that is not under pressure from both old and new pests and diseases, which, in synergy with climate change, significantly reduce their vitality. For example, narrow-leaved ash, an important component of lowland forest stands, has already reached a critical stage of dieback. In our editorials we have frequently discussed the above issue, giving importance to all moves at the global and national level that are aimed at taking care of the great forest wealth in the Republic of Croatia. The Croatian media has recently been addressing the results of the 2021 population census. This has again put demographers in the centre of attention: they have been repeating the same story for decades, yet the decision makers do not take any heed. We may also draw a parallel with our decade-long story about the name of the competent ministry, and particularly about the attitude of the line ministry towards the forest, a resource that covers almost half of the country. Interestingly, demographers have also noticed the role of the public enterprise Croatian Forests, which manage state forests over the entire state territory. They propose decentralisation: "Today, the company Croatian Forests manages forests over the entire territory of Croatia, which is, conditionally said, centralised. Management should really be left to the local communities so that they bear the responsibility, but also have the same authority." For example, in the Gorski Kotar region, where over 70 percent of the territory is covered with forests, the seventies and eighties of the 20th century was the period in which forestry was aimed at fostering the prosperity of the local community, as well as developing and raising the living standard of the people and the region. Today, it is an area affected by depopulation, while the forest resources at its disposal are either not used or are used elsewhere. A similar story is true for Slavonia, which possess the most valuable commercial forests, but which generate added value further from the place where they grow. This wealthy region has recently recorded the most severe emigration.

Can the above trend be reversed? The adoption of strategic plans and their implementation should be based on comparative advantages of a certain region. We believe that focusing only on the management of raw materials without management of space and without strategic employment of personnel puts the rural areas of Croatia in an even more unfavourable position and leads to increased depopulation of the area. Economic policies which favour close interest groups have already taken their toll. Generous incentives from European funds motivate users to instantly engage in a certain activity, but the ultimate goal of increasing production is usually not met. Quite frequently, the beneficiaries of funds do not even live in the area for which the funds have been allocated. The Forest Acts and the Agricultural Land Act provide for the demarcation of forest and agricultural land according to their natural state and harmonisation with the land registry. Their implementation would facilitate the management of forests and eliminate problems arising from leases of large areas for grazing, the results of which highly questionable. Regrettably, this vital prerequisite for better management of space and for retaining, and even increasing the number of inhabitants in it, has not been fulfilled. Similar to other segments, years go by, but the laws and strategies set out by the goals are not implemented. The organisation of forestry in some neighbouring countries may offer answers to our questions. Austrian and Hungarian forestry companies are not engaged only in the production and sale of wood assortments: their activities are also related to renewable energy sources and nature protection, which expands the possibility of employment for the local population. Ultimately, their foresters have better income and higher living standard.

Editorial Board

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Izvorni znanstveni članci – Original scientific papers
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DIMENZIJSKE I MASENE ZNAČAJKE FORVARDERA

DIMENSIONAL AND MASS CHARACTERISTICS OF FORWARDERS

Tomislav PORŠINSKY[1], Zdravko PANDUR[1], Zoran BUMBER[2], Mihael LOVRINČEVIĆ[1], Branko URSIĆ[1], Andreja ĐUKA[1]*

SAŽETAK

Izvoženje drva forvarderima, obilježava kotrljanje drva na kotačima, prihvat i sakupljanje sortimentnom metodom izrađenoga drva hidrauličnom dizalicom, iz čega proizlazi i zahtjev za paralelnom mrežom sekundarnih šumskih prometnica međusobnoga razmaka dvostrukoga dosega dizalice.

Rad se bavi prikazom: 1) dimenzijskih i masenih značajki forvardera u svijetlu norme ISO 13860 (2016) te 2) plana raspodjele tereta forvardera kojega je razvio njemački Kuratorij za šumski rad i šumsku tehniku (KWF), s ciljem pomoći šumarskim stručnjacima pri nabavci, odnosno korištenju ovih šumskih vozila.

Za primjerni forvarder odabran je teški osmokotačni forvarder Komatsu 875, za koji su na osnovi mjerenja prikazane njegove dimenzijske i masene značajke, kao i plan raspodjele tereta s ciljem njegove ocjene.

Kritički osvrt je dan i na normu ISO 13860 (2016) s obzirom na neobuhvaćanje nekih dimenzijskih (duljina i visina prednjeg te stražnjeg prepusta forvardera, kutovi i polumjeri prohodnosti vozila) i masenih (položaj točke težišta) pokazatelja forvardera, a koje opisuju i/ili služe modeliranju njegove kretnosti pri izvoženju drva s obzirom na smjer i uzdužni nagib terena. Isto tako, norma izrijekom ne spominje niti jedan pokazatelj okolišne pogodnosti (npr. nominalni tlak na podlogu).

KLJUČNE RIJEČI: prohodnost i kretnost forvardera, ISO 13860 (2016), raspodjela tereta

1. UVOD
INTRODUCTION

Izvoženje drva forvarderima naslanja se na dugu tradicijsku uporabu životinjsko-kolskih sprega, a razvoj forvardera na traktore s (polu)prikolicom (Drushka i Konttinen 1997). Prvi forvarder Brunett 350 Boxer je proizveden u Švedskoj 1962. godine (Nordfjell i dr. 2019), a prvi forvarderi na području spačvanskih šuma koriste se od 1971. godine (Slabak 1983). Izvoženje drva forvarderima, predstavlja poseban oblik privlačenja drva, koji obilježava kotrljanje drva na kotačima, prihvat i sakupljanje sortimentnom metodom izrađenoga drva hidrauličnom dizalicom, iz čega proizlazi i zahtjev za paralelnom mrežom traktorskih vlaka međusobnoga razmaka dvostrukoga dosega dizalice (Poršinsky 2005, Poršinsky i dr. 2011).

Forvarder je samohodno i samoutovarno vozilo konstruirano za izvoženje stabala ili njihovih dijelova (ISO 6814, 2009), a sastoji se od dvije uzglobljene šasije (okvira). Prednji (pogonski) dio vozila i pogonjena poluprikolica (nosač tereta) s pridodanom hidrauličkom dizalicom spojeni su

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uzdužnim i poprečnim zglobom te imaju mogućnost gibanja u vodoravnoj i uspravnoj ravnini (Horvat 1993A). Upravljanje forvarderom (skretanje vozila), vrši se pomoću dva hidraulička cilindra uzdužnoga zgloba, promjenom kuta prednjeg i stražnjeg dijela vozila u vodoravnoj ravnini. Poprečni zglob omogućuje svladavanje terenskih prepreka gibljivošću u uspravnoj ravnini, čime je omogućeno njihanje prednjeg i stražnjeg dijela forvardera. Pri utovaru drva dizalicom poprečni je zglob forvardera blokiran u cilju osiguranja bočne stabilnosti vozila.

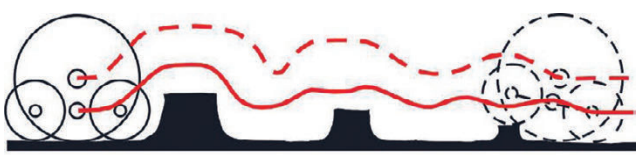
Prema izvedbi kretnoga sustava forvarderi se dijele na kotačne (slike 1A – 1E) i gusjenične (slika 1F), a kotačni prema broju kotača na četverokotačne (slika 1A), šestokotačne (slika 1B), osmokotačne (slika 1C) i desetokotačne forvardere (slika 1D). Samo kod šestokotačnih forvardera prednji kotači (pneumatici) su većega promjera, dok su kod ostalih kotačnih forvardera istih dimenzija. Iako je kod forvardera hidraulična dizalica osnovni način prihvata drva, proredni forvarderi često se opremaju stražnjom daskom i vitlom za sakupljanje drva iz neprometnih terena za šumska vozila (slika 1A). Posebno treba istaknuti da je u zadnjem deset-

Slika 1. Različite izvedbe forvardera
Fig. 1 Different forwarder designs

ljeću sve prisutnije opremanje kotačnih forvardera dodatnim vitlom (slika 1E), čije uže nema namjenu prihvata/sakupljanja drva, već sidrenja i/ili dodatne trakcije vozila, čime je forvarderima siguran i djelotvoran rad proširen sa 30 % na 55 % uzdužnog nagiba terena (Holzfeind i dr. 2020).

Jednostruka prednja i stražnja osovina značajne su samo za četverokotačne (proredne) forvardere, dok su forvarderi s većim brojem kotača svi opremljeni stražnjom (šestokotačni), a osmokotačni i prednjom njihajućom (bogi) osovinom s kotačima u tandem rasporedu. Oko bogi osovine prisutne su česte terminološke dvojbe je li ona jednostruka, odnosno dvostruka osovina ili se radi o udvojenim kotačima. Pod udvajanjem kotača osovine podrazumijeva se njihov položaj jedan do drugoga, dok su kod bogi osovine oni smješteni jedan iza drugog u tzv. tandem rasporedu. Sa stajališta raspodjele opterećenja bogi osovina je jednostruka, a dvostruka sa stajališta raspodjele pogona na kotače, odnosno djelovanja na tlo. Zbog spoznaje da cjelokupan teret utovarenoga drva opterećuje stražnju osovinu forvardera (Poršinsky i Horvat 2005), kod desetokotačnih forvardera (slika 1D) stražnja bogi osovina izvodi sa tri kotača u tandem rasporedu u cilju smanjenja sabijanja tla (Starke i dr. 2020), od kojih je zadnji vučeni – slobodnokotrljajući kotač (Ponsse) ili pogonski kotač (HSM). U odnosu na jednostruku osovinu, bogi osovinu forvardera obilježava: 1) veća nosivost i bolja kretnost vozila s obzirom na broj pogonskih kotača (Horvat 1993B,) 2) veća stabilnost vozila pri svladavanju površinskih prepreka (Makkonen 1989 – slika 2) te 3) okolišna pogodnost uslijed manjih dodirnih tlakova na tlo većeg broja kotača i njihove veće dodirne površine (Poršinsky i dr. 2011). U uvjetima ograničene nosivosti šumskog tla kotači jednostruke osovine forvardera opremaju se lancima, a njihajuće bogi osovine polugusjenicama (Ireland 2006, Poršinsky i dr. 2020).

Forvardere pogone dizel motori s prednabijanjem. Do 1989. prevladavaju šestokotačni forvarderi s mehaničko – hidrodinamičkom transmisijom (s konventerom zakretnoga momenta), a od 2010. osmokotačni forvarderi s bogi osovinom na prednjoj i stražnjoj šasiji vozila te hidrostatsko – mehaničkom transmisijom (Nordfjell i dr. 2010). Mogućnost hibridnog pogona forvardera trenutno je još u razvoju, odnosno na razini prototipa (Pandur i dr. 2021). Uspoređujući značajke forvardera 1970. i 2010. godine, Nordfjell i dr. (2019) zaključuju da tijekom vremena forvarderi postaju sve teži, na osnovi porasta prosječnih vrijednosti njihove: 1) neto mase (9,2 t → 17,3 t), 2) nosivosti (11,5 t → 14,5 t), 3) ukupne mase s deklariranim teretom (20,4 t → 31,8 t), 4) snage motora (71,6 kW → 158,6 kW), 5) zakretnog momenta motora (318 Nm → 907 Nm), 6) odnosa snage motora i ukupne mase (3,44 kW/t → 5,00 kW/t) te 7) odnosa zakretnoga momenta motora i ukupne mase (15 Nm/t → 29,3 Nm/t). Isti autori, navode da se je i podizni moment hidraulične dizalice povećavao s obzirom na neto masu forvardera.



Prema – *According to*: Makkonen (1989)

Slika 2. Usporedba kretanja bogi i jednostruke osovine
Fig. 2 Comparison of axle movement on bogie and single axle

Osim udaljenosti privlačenja drva, proizvodnost je forvardera najznačajnije utjecana obujmom drva koji se izvozi u jednom traktorskom ciklusu, stoga se oni najčešće dijele s obzirom na njihovu deklariranu nosivost (Athanassiadis i dr. 1999) na: 1) lake (< 10 t), 2) srednje teške (10 – 12 t) te 3) teške (> 12 t). Analizirajući stanje na tržištu forvardera, Nordfjell i dr. (2019) predlažu novu podjelu forvardera na osam razreda njihove nosivosti: 1) Micro (< 2 t), 2) XXS (2 – 5 t), 3) XS (5 – 8 t), 4) Small (8 – 11 t), 5) Medium (11 – 14 t), 6) Large (14 – 17 t), 7) XL (17 – 20 t) te 8) XXL (> 20 t).

Cilj je ovoga rada približiti šumarskim stručnjacima dimenzijske i masene značajke forvardera sukladno normi ISO 13860 (2016), te značenje KWF-ovog dijagrama raspodjele opterećenja s obzirom na duljinu utovarenoga drva listača, odnosno četinjača, kao alat za ocjenjivanja pogodnosti forvardera prilikom njihove nabavke, odnosno planiranja izvoženja drva. Navedeno će biti prikazano na primjeru teškog osmokotačnoga forvardera Komatsu 875.

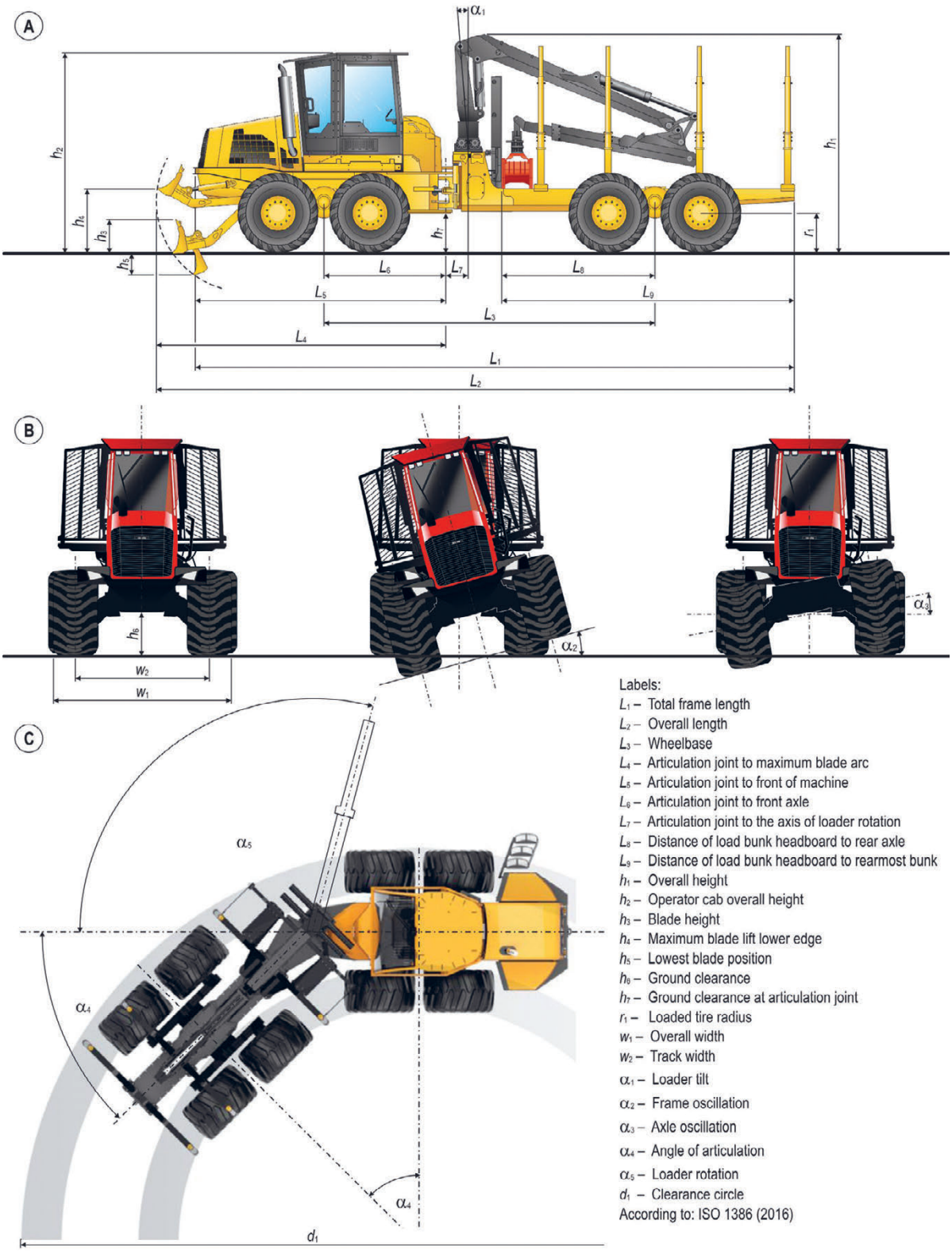
2. ISO 13860 (2016)

Norma ISO 13860 (2016) definira osnovne dimenzijske i masene značajke forvardera koje su prikazane na slici 3, temeljem kojih Horvat i dr. (2004) izrađuju morfološku analizu forvardera s ciljem potpore: 1) odabiru novih vozila šumarskim stručnjacima, 2) određivanju najpovoljnije uporabe forvardera u različitim uvjetima rada te 3) određivanju okvirnih dimenzija pri konstrukciji novih forvardera. Navedena norma dimenzije forvardera određuje kroz 13 duljina, 15 visina, 4 širine, 6 kutova, 2 površine presjeka te po jedan polumjer i promjer.

Duljine i visine forvardera prikazuje slika 3A, a širine, klirens te vertikalnu gibljivost forvardera slika 3B. Horvat i dr. (2004) navode da je za sve forvardere značajno prevladavanje visine (h_1) nad širinom vozila (w_1), što nepovoljno utječe na njegovu bočnu stabilnost. U odnosu na duljinu forvardera (L_1, L_2), ali i međuosovinski razmak (L_3), posebno treba istaknuti asimetrično postavljeni upravljački zglob (L_4, L_5, L_6), zbog ugradnje hidraulične dizalice na stražnji okvir vozila, ali i zahtjeva za duljinom utovarnog prostora (L_9). Za kretnost forvardera pri izvoženju drva, koju između ostalih

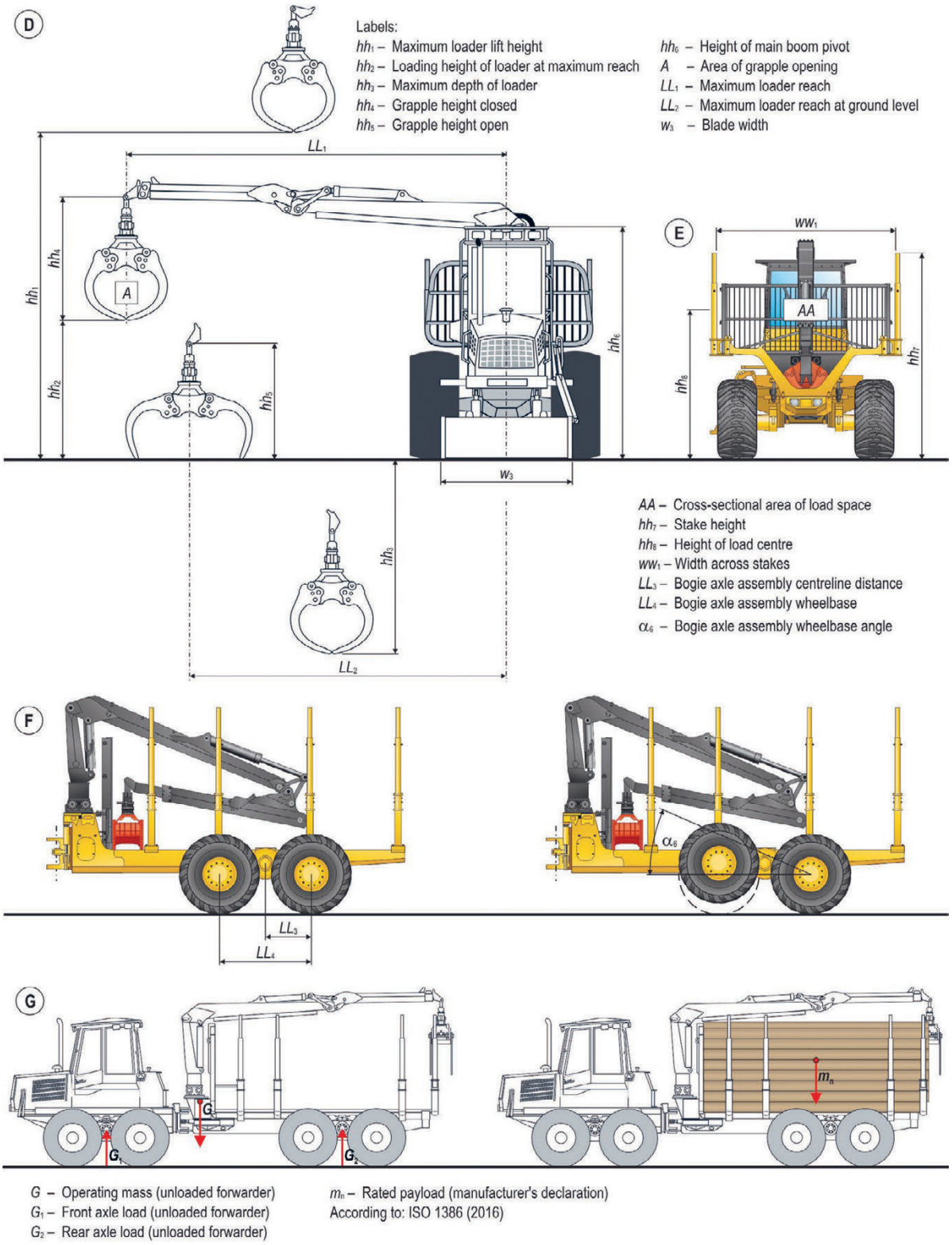
pokazatelja određuje raspodjela osovinskog opterećenja nominalno natovarenoga vozila, pored međuosovinskog razmaka (L_3), utječe i položaj hidraulične dizalice u odnosu na zglob vozila (L_7), kao i položaj uzglavlja utovarnoga prostora u odnosu na stražnju osovinu vozila (L_8).

Pokazatelj prohodnosti forvardera pri kretanju forvardera po površinskim preprekama (kamenitim terenima) svakako je klirens vozila (h_6), ali i kut oscilacije prednje i stražnje šasije vozila (α_2) uslijed mogućnosti zakretanja upravljačkog zgloba i u uspravnoj ravnini, čime je umanjeno



Slika 3. Dimenzijske i masene značajke forvardera – 1. dio
Fig. 3 Dimensional and mass characteristics of forwarders – part 1

nepovoljno prevladavanje visine nad širinom forvardera. Vertikalnu gibljivost forvardera pri kretanju po površinskim preprekama osigurava i kut oscilacije osovine (α_3), koja je tipična samo za šestokotačne forvardere kojima je ugrađena jednostruka prednja oscilirajuća osovina. Bitno je napomenuti da sve visine forvardera, kao i njegova ukupna širina ovise o dimenzijama pneumatika kojima su opremljeni. Posebno treba istaknuti da se forvarder može registrirati ako mu vanjske gabaritne dimenzije ispunjavaju uvjete Pravilnika o tehničkim uvjetima vozila u prometu



Slika 3. Dimenzijske i masene značajke forvardera – 2. dio
Fig. 3 Dimensional and mass characteristics of forwarders – part 2

na cestama (NN 85/16, 24/17, 70/19, 60/20), čime izostaju troškovi kamiona s niskopodnom prikolicom pri premještanju forvardera s jednog na drugo šumsko radilište.

Kuteve skretanja forvardera i zakretanja hidraulične dizalice prikazuje slika 3C. Zglobno upravljanje forvarderom, odnosno kut loma zgloba u horizontalnoj ravnini (α_4) omogućava forvarderu manji vanjski promjer okretanja (d_1) u odnosu na vozila kojima se upravlja promjenom kuta prednjih i/ili stražnjih kotača vozila, dok je kut zakretanja hidrauličke dizalice (α_5) pokazatelj njene dobrote pri sakupljanju izrađenog drva.

Dimenzijske značajke hidraulične dizalice kojom je opremljen forvarder (odnosno stupa dizalice, podiznog, produžnog i izvlačnog kraka), a koje su bitne za djelotvornost utovara i istovara drva prikazuje slika 3D. Posebno treba istaknuti da je najveći doseg dizalice na razini tla (LL_2) uvijek ima manju vrijednost od najvećeg dosega dizalice (LL_1), što treba uvažiti pri planiranju i obilježavanju paralelne mreže traktorskih vlaka na terenu. Najveća visina podizanja dizalice (hh_1) utječe na visinu složajeva drva pri istovaru drva na pomoćnome stovarištu, a najveća dubina prihvata drva dizalicom (hh_3) na mogućnost sakupljanja drva ispod razine tla (duboki kanali, vrtače, ...). Navedeni pokazatelji dobrote dizalice pri utovaru i istovaru drva utjecani su i visinom hvatala s rotatorom (hh_5) kojima je hidraulična dizalica opremljena, kao i visinom osovine stupa dizalice i podiznoga kraka (hh_6).

Dimenzijske značajke poprečnoga presjeka utovarnoga prostora forvardera prikazane na slici 3E. Uz širinu (ww_1), površine presjeka (AA) te visine držača tereta od tla (hh_7), norma ISO 13860 (2016) poznaje i visinu težišta tereta (hh_8) za koju Makkonen (1989) navodi da je bitan pokazatelj bočne stabilnosti forvardera.

Većina je ovodobnih forvardera opremljena stražnjom njihajućom bogi osovinom iz razloga što ona preuzima masu utovarenoga drva. Značajke bogi osovine forvardera prikazane su na slici 3F, s dvije dimenzije: 1) razmakom osovina tandem kotača (LL_4) te 2) kutem bogija kojim osciliraju kotači u tandem rasporedu pri prelaženju površinskih nepravilnosti (α_6). Ova vertikalna oscilacija još je jedno tehničko rješenje povećanja bočne stabilnosti forvardera pri kretanju po površinskim preprekama (Makkonen 1980), a navedene dimenzijske značajke bogi osovine određuju i visinu prepreke koju forvarder pri kretanju može svladati.

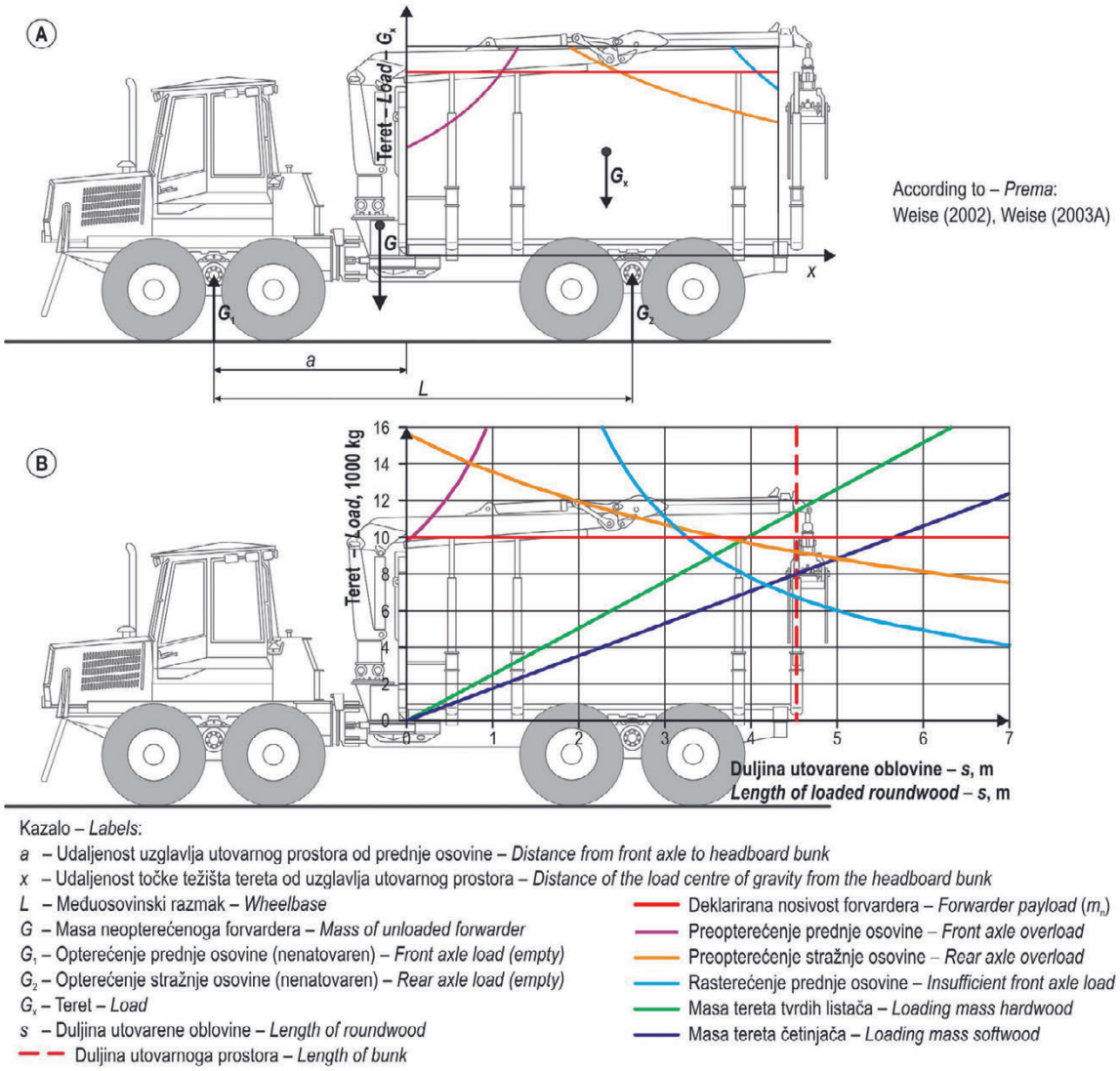
Iako norma ISO 13860 (2016) poznaje više masenih značajki, za odabir forvardera i planiranje izvoženja drva, bitne su one prikazane na slici 3G: 1) deklarirana nosivost forvardera od strane proizvođača (m_n), 2) masa nenatovarenoga forvardera (G) te njena raspodjela – opterećenje na 3) prednju (G_1) i 4) stražnju (G_2) osovinu. Norma predviđa i iskaz dopuštenog opterećenja prednje i stražnje osovine kojima je opremljen forvarder od strane proizvođača. Od masenih značajki forvardera, neovisno o njihovim proizvođačima posebno treba istaknuti ustaljenost: 1) raspodjele neto mase forvardera, 60 % na prednju te 40 % na stražnju osovinu i 2) odnosa nosivosti forvardera i mase nenatovarenoga forvardera, koji Nordfjel i dr. (2019) nazivaju indeks opterećenja te navode da on za današnje forvardere iznosi ~ 0,80, dok je kod forvardera iz 1970. godine iznosio ~ 1,0. Pad nosivosti u odnosu na neto masu u proteklome razdoblju, obrazlažu činjenicom da je nosivost forvardera sporije rasla u odnosu na masu nenatovorenoga vozila uslijed ugradnje snažnijih pogonskih motora te većih hidrauličnih dizalica.

Dodatno, norma ISO 13860 (2016) obuhvaća i specifikacije pneumatika kojima je forvarder opremljen.

3. PLAN RASPODJELE TERETA FORVARDERA
LOAD DISTRIBUTION PLAN FOR FORWARDERS

Na osnovi dimenzijskih i masenih značajki forvardera njemački Kuratorij za šumski rad i šumsku tehniku (KWF) razvio je Plan raspodjele tereta forvardera na horizontalnoj podlozi (Weise 2002, Weise 2003A) s ciljem: 1) ocjene dobrote njihove konstrukcije prilikom nabavke te 2) pomoći pri planiranju izvoženja drva listača, odnosno četinjača.

Proizvođači forvardera deklariraju nosivost (dopušteno opterećenje) forvardera, pri čemu ne uzimaju u obzir vrstu drva, kao ni duljinu utovarenoga drva. S obzirom na konstrukciju forvardera te duljinu izrađene oblovine, utovareno drvo, ovisno o položaju težišta tereta, više opterećuje prednju ili stražnju osovinu vozila. U cilju djelotvornoga korištenja forvardera potrebno je podjednako opteretiti osovine vozila ili rasporediti opterećenje s obzirom na nosivost osovina, odnosno radi upravljanja vozilom zadržati najmanje opterećenje prednje osovine forvardera (Weise 2002). Navedenim, Plan raspodjele tereta forvardera zasnovan je na četiri korisnička zahtijeva (Weise 2003A): 1) najveći teret utovarenoga drva neovisno o njegovoj duljini i položaju težišta, ne smije biti veći od deklarirane nosivosti forvardera od strane proizvođača uslijed čvrstoće konstrukcije utovarnoga prostora (izraz 1), 2) najveće dopušteno opterećenje prednje (izraz 2) i 3) stražnje osovine (izraz 3) ne smije se prekoračiti (pri čemu treba uzeti u obzir i zbroj nosivosti pneumatika po osovini) te 4) opterećenje prednje osovine ne smije pasti ispod 20 % mase opterećenoga forvardera (izraz 4). Plan raspodjele tereta forvardera s obzirom na položaj točke težišta tereta (udaljenosti od uzglavlja utovarnoga prostora), zasnovan je na razradi momentnih jednadžbi (izrazi 2 do 4), a vizualiziran je sa četiri krivulje na dijagramu prikazanim na slici 4A iz kojih se može zaključiti: 1) utovar kratkog drva (težište tereta ispred prednjih kotača stražnje osovine) dovodi do preopterećenja prednje osovine forvardera, 2) teret sa težištem u uskom



Slika 4. Plan raspodjele tereta forvardera
Fig. 4 Load distribution plan for forwarders

rasponu oko središta stražnje osovine osigurati će korištenje deklarirane nosivosti forvardera, 3) pomicanjem težišta tereta iza stražnje osovine dovesti će do njenoga preopterećenja, odnosno 4) daljnje pomicanje težišta tereta ka kraju utovarnoga prostora polučiti će rasterećenje prednje osovine forvardera te gubitak upravljivosti vozilom.

$$G_x \leq m_n \tag{1}$$

$$G_x \leq \frac{G_{1\_alow} \cdot L}{L - a - x} \tag{2}$$

$$G_x \leq \frac{G_{2\_alow} \cdot L}{a + x} \tag{3}$$

$$G_x \leq \frac{G_1 - 0{,}2 \cdot G}{\frac{x + a}{L} - 0{,}8} \tag{4}$$

$$G_x = A \cdot f \cdot \rho \cdot s \tag{5}$$

$$s = 2 \cdot x \tag{6}$$

gdje su:

m_n deklarirana nosivost forvardera (kg)
G_x masa utovarenoga drva (kg)
G_1 opterećenje prednje osovine nenatovarenoga forvardera (kg)
G masa nenatovarenoga forvardera (kg)
G_{1_alow} dopušteno opterećenje prednje osovine (kg)
G_{2_alow} dopušteno opterećenje stražnje osovine (kg)
x udaljenost točke težišta tereta od uzglavlja utovarnoga prostora (m)
s duljina utovarenoga drva (m)
a udaljenost uzglavlja utovarnog prostora od prednje osovine (m)

L međuosovinski razmak forvardera (m)
A površina poprečnoga presjeka utovarnoga prostora (m^2)
f iskoristivost (popunjenost) poprečnoga presjeka utovarnoga prostora (%)
ρ gustoća utovarenoga drva (kg/m^3)

Pretpostavke izračuna mase utovarenoga drva (izraz 5) ovisno o njegovoj duljini su: 1) ispunjen poprečni presjek utovarnoga prostora, 2) pri čemu je popunjenost poprečnog presjeka 70 % (radi transformacije prm u m^3), 3) gustoća drva tvrdih listača od 1000 kg/m^3, a četinjača od 700 kg/m^3 (Weise 2003B). Korištenjem izraza 6, transformiran je dijagram prikazan na slici 4A u dijagram koji prikazuje slika 4B, koji je daleko razumljiviji korisnicima jer prikazuje krivulje deklarirane nosivosti forvardera, preopterećenja prednje i stražnje osovine te rasterećenja prednje osovine ovisno o duljini utovarene oblovine.

Posebno treba istaknuti da dijagram slike 4B, predstavlja nepovoljne dimenzijske i masene značajke forvardera, kod kojega se ne može doseći deklarirana nosivost pri utovaru drva listača i četinjača zbog preopterećenja stražnje osovine te posljedično rasterećenja prednje osovine. Uzrok navedenome su: 1) manje opterećenje prednje osovine nenatovarenoga vozila, 2) nepovoljan položaj uzglavlja utovarnoga prostora, koje je previše pomaknuto ka stražnjoj osovini vozila u odnosu na međuosovinski razmak te 3) prevelika udaljenost težišta utovarenoga drva od prednje osovine forvardera (Weise 2003A).

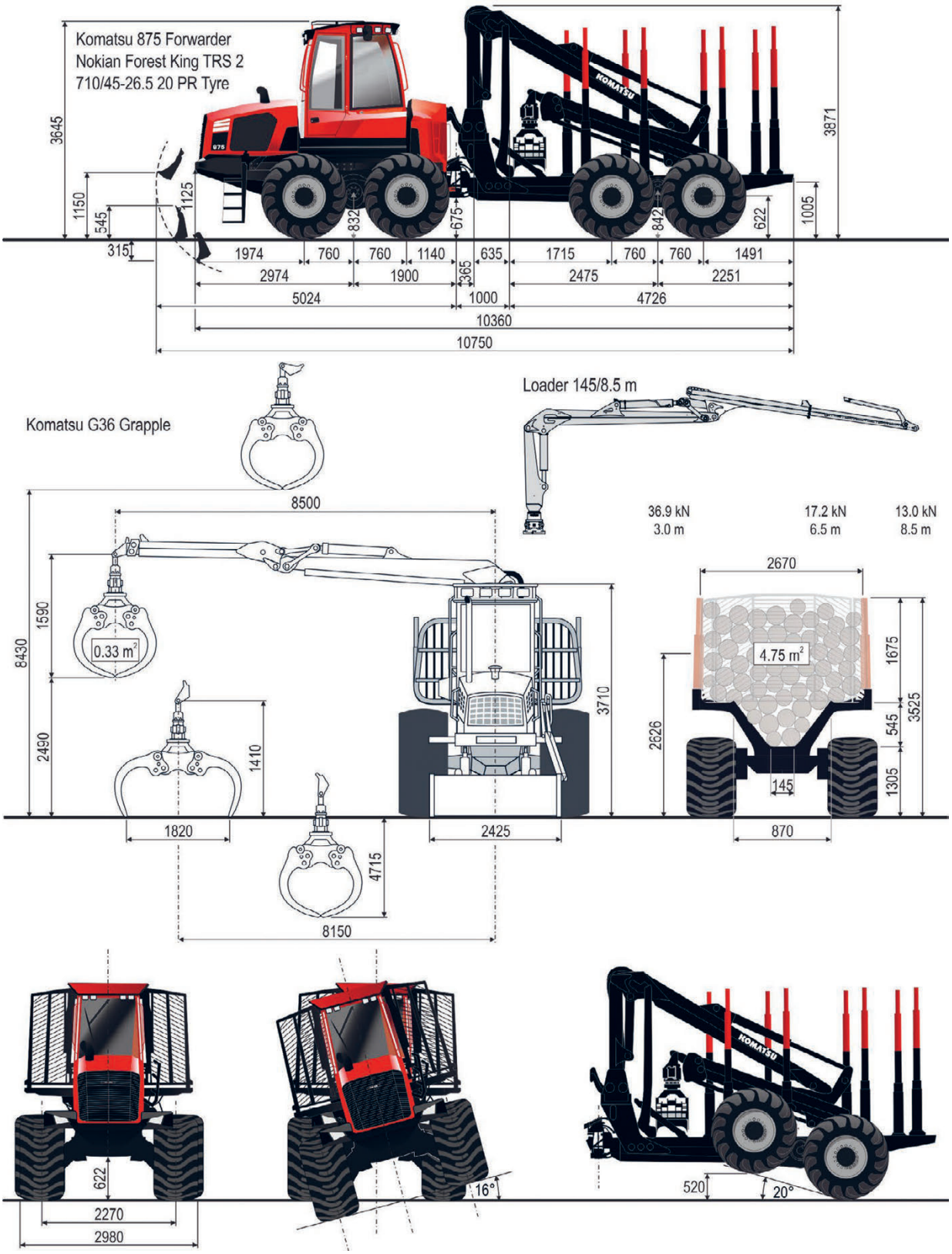
4. DIMENZIJSKE I MASENE ZNAČAJKE FORVARDERA KOMATSU 875
DIMENSIONAL AND MASS CHARACTERISTICS OF KOMATSU 875 FORWARDER

U mehaničkoj radionici Radne jedinice Prijevoz, mehanizacija i graditeljstvo Uprave šuma podružnice Bjelovar, provedena je izmjera dimenzijskih i masenih značajki primjernog osmokotačnog forvardera Komatsu 875 sukladno normi ISO 13860 (2016). Za izmjeru dimenzijskih značajki forvardera korištene su geodetska letva, mjerna vrpca, laserski daljinomjer, kutnik i digitalni kutomjer, a za izmjeru masenih značajki prijenosne 10-tonske vage Telub (slika 5A).

Komatsu 875 je teški forvarder neto mase 21.385 kg te deklarirane nosivosti 16.000 kg. Vozilo pokreće šest-cilindarski dizelski motor s prednabijanjem (AGCO Power 74-AWF), stapajnog obujma 7.400 cm^3, najveće snage 190 kW pri 1900 min^{-1} i zakretnog momenta 1130 Nm pri 1500 min^{-1}, koji udovoljava zahtjevima EURO norme V za emisiju ispušnih plinova. Prijenos snage obavlja se hidrostatsko-

Slika 5. Mjerenja nekih značajki forvardera Komatsu 875
Fig. 5 Measurements of some Komatsu 875 forwarder features

-mehaničkom transmisijom, gdje dizel motor pogoni hidrostatski sustav forvardera, koji se sastoji od pumpe i hidromotora. Hidromotor pokreće razvodnik pogona s kojega se snaga prenosi kardanskim vratilima na prednji, odnosno stražnji diferencijal. Snaga se sa diferencijala vratilima prenosi na zupčanički sustav bogi osovina unutar kojega se



Slika 6. Dimenzijske značajke forvardera Komatsu 875
Fig. 6 Dimensional Characteristics of Komatsu 875 forwarder

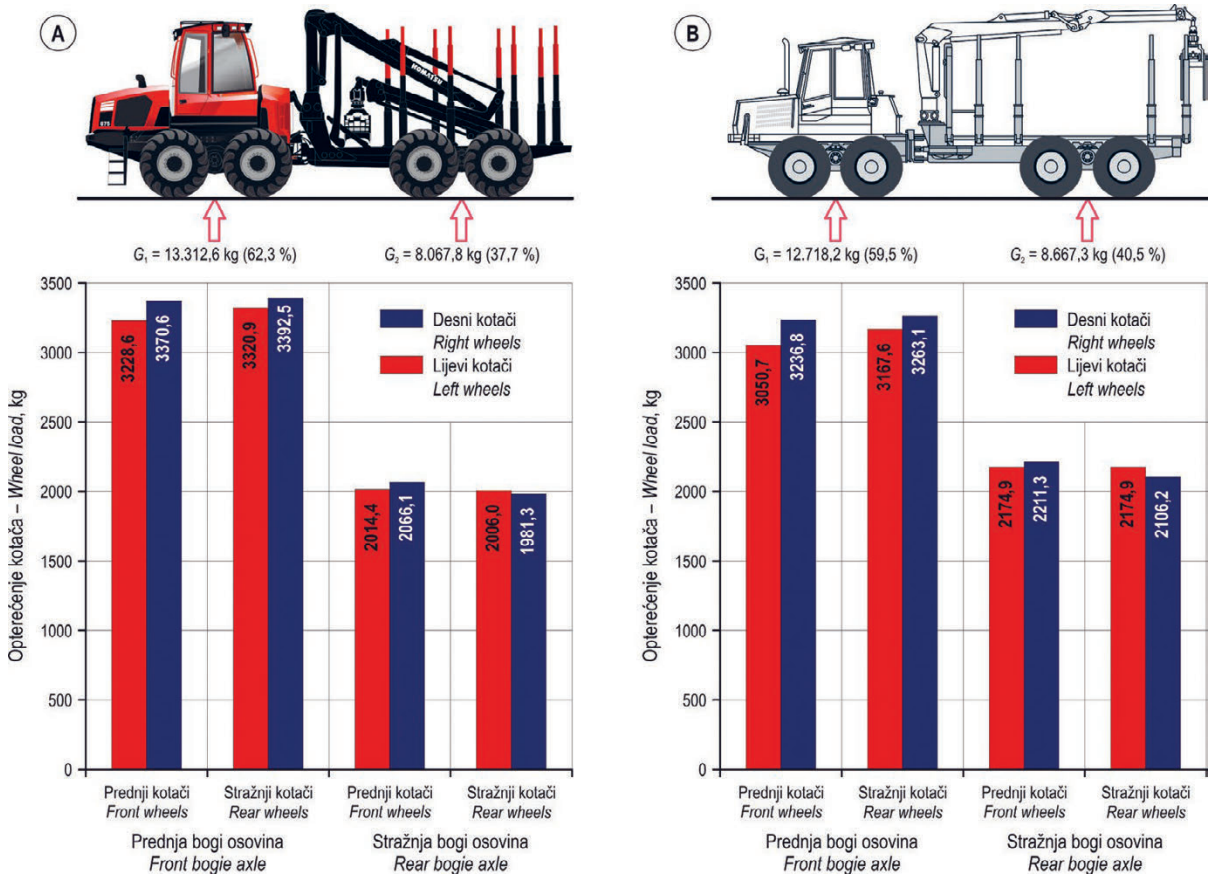
pogone planetarni reduktori lijevog i desnog para tandem kotača. Na ovaj je način omogućena promjena stupnja prijenosa bez zaustavljanja toka snage uz računalnu kontrolu prijenosa snage. Uusitalo (2010) navodi da većina skandinavskih šumskih vozila koristi sustav hidrostatsko-mehaničke transmisije zbog lakšeg održavanja, dugog vremena uporabe te lakše kontrole snage motora u teškim uvjetima rada. Indeksni pokazatelji forvardera Komatsu 875, poput: 1) odnosa snage motora i mase forvardera s deklariranim teretom (5,08 kW/t), 2) odnosa zakretnog momenta i mase forvardera s deklariranim teretom (30,23 Nm/t) te 3) odnos nosivosti i neto mase (0,75), u skladu su s pokazateljima ovodobnih forvardera (Nordfjell i dr. 2019).

Uslijed opremljenosti forvardera Komatsu 875 prednjom daskom, ukupna duljina vozila iznosi 10,75 m (slika 6). Uz asimetrično postavljeni uzdužni zglob sa kutom loma prednje i stražnje šasije od ±42° (slika 5B) te duljinom prednje šasije od 5,024 m i stražnje šasije od 5,726 m, forvarder Komatsu 875 ostvaruje relativno mali vanjski promjer okretanja vozila od 31,25 m, odnosno unutarnji polumjer okretanja vozila od 12,65 m. Širina vozila od 2,98 m odgovara širini traktorskih vlaka od 3,5 do 4 m.

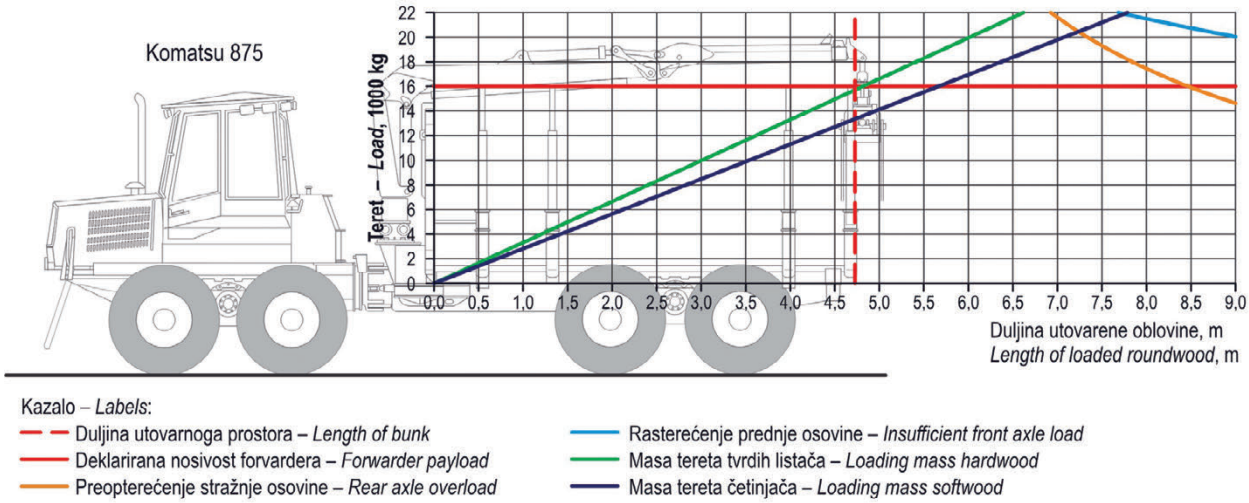
Vertikalnu gibljivost forvardera Komatsu 875 pri kretanju po nepravilnostima terena osigurava kut zakretanja poprečnoga zgloba od ±16° (slika 5C), ali i kut osciliranja tandem kotača bogi osovine od ±20° (slika 5D) koji omogućuje svladavanje površinskih prepreka visine <52 cm uz zadržavanje bočne stabilnosti forvardera.

Forvarder je opremljen hidrauličkom dizalicom Komatsu 145F, mase 2400 kg i dosega 8,5 m te najvećega podiznog momenta 145 kNm, odnosno najvećeg zakretnog momenta 38 kNm. Kut zakretanja dizalice iznosi ±192°, najveća visina podizanja tereta 8,43 m te mogućnost prihvata drva 4,71 m ispod razine tla (slika 6), opisuju njene velike mogućnosti pri utovaru i istovaru drva, što je posebno značajno zbog spoznaje o utroščima vremena rada dizalicom <60 % u strukturi ukupnoga vremena turnusa (Piskunov 2021). Ipak najveći doseg dizalice na razini tla od 8,15 m ne osigurava prihvat izrađenoga drva sa paralelne mreže traktorskih vlaka međusobnoga razmaka 20 m. U cilju smanjenja gaženja i sabijanja šumskoga tla, ovaj problem se može riješiti: 1) usmjerenim rušenjem stabala okomito na traktorske vlake i/ili 2) nabavkom forvardera sa dodatnim izvlačnim krakom, odnosno dosegom dizalice od 10 m.

Poprečni presjek utovarnog prostora iznosi 4,75 m^2, duljine je 4,726 m te zapremine 22,45 prm. Uz iskorištenje/ispunjenost poprečnog presjeka od 70 % i gustoću drva od 1000 kg/m^3 (Weise 2002) dosiže se deklarirana nosivost forvar-



Slika 7. Masene značajke značajke forvardera Komatsu 875
Fig. 7 Mass characteristics of Komatsu 875 forwarder



Slika 8. Plan raspodjele tereta forvardera Komatsu 875
Fig. 8 Load distribution plan for Komatsu 875 forwarder

dera od 16 t. Uzglavlje je utovarnog prostora udaljeno 2,9 m od prednje i 2,475 m od stražnje osovine (slika 6), čime masa utovarenoga drva duljine ~ 4,8 u potpunosti opterećuje stražnju osovinu, što je u skladu s prethodnim objavama (Poršinsky i Horvat 2005).

Prednja i stražnja bogi osovina forvardera Komatsu 875 su iste – NAF PTA 76 za koje proizvođač navodi najveće dopušteno statičko opterećenje od 360 kN te najveće dopušteno dinamičko opterećenje od 290 kN (www.nafaxles.com). Kotači prednje i stražnje osovine opremljeni su pneumaticima istih dimenzija 710/45-26.5 20 PR (Nokian Forest King TRS 2) – širine 710 mm, promjera 1340 mm, opterećenog statičkog polumjera 618 mm, kotrljajućeg opsega 4103 mm te najvećeg tlaka punjenja zrakom 500 kPa (Nokian 2021). Proizvođač pneumatika navodi da za Komatsu 875 prednje gume trebaju biti napunjenjene tlakom zraka od 400 kPa koji osigurava njihovu nosivost od 5,6 t/gumi pri brzini kretanja < 10 km/h, odnosno stražnje sa tlakom zraka od 500 kPa koji pri istoj brzini kretanja osigurava njenu nosivost od 6,9 t/gumi. Navedenim, nosivost bogi osovine nije kriterij dopuštenih osovinskih opterećenja forvardera Komatsu 875, već zbroj nosivosti pneumatika kotača prednje (22,4 t) i stražnje (27,6 t) bogi osovine kojima je vozilo opremljeno.

Norma ISO 13860 (2016), pri iskazivanju osovinskih opterećenja neopterećenoga forvardera na horizontalnoj podlozi ne određuje položaj hidraulične dizalice, odnosno je li ona složena u transportnome položaju ili ispružena što je precizniji ulazni podatak za izračun Plana raspodjele tereta. Rezultate vaganjem utvrđenih opterećenja kotača te osovinskih opterećenja za nenatovareni forvarder Komatsu 875 sa složenom dizalicom u transportnome položaju prikazuje slika 7A, a sa ispruženom dizalicom slika 7B. Odstupanje neto mase forvardera, od 5,1 kg pri ove dvije inačice vaganja su zanemariva (neto masa forvardera sa složenom dizalicom u transportnom položaju iznosi 21.380,4 kg, a sa ispruženom dizalicom 21.385,5 kg). Opterećenje prednje osovine forvardera sa dizalicom složenom u transportnom položaju iznosi 13.312 kg (62,3 % neto mase), a opterećenje stražnje osovine 8067,8 kg, odnosno 37,7 % neto mase. Kod vaganja forvardera sa ispruženom dizalicom, došlo je do promjene raspodjele opterećenja po osovinama, gdje je prednja osovina opterećena sa 12.718,2 kg (59,5 %) te stražnja sa 8667,3 kg (40,5 %), uslijed premještanja mase podiznog, produžnog i izvlačnog kraka ka stražnjoj osovini vozila. Neovisno o položaju hidrauličke dizalice pri vaganju forvardera, zbroj ukupnih opterećenja svih desnih kotača iznosi 50,6 % neto mase vozila, odnosno zbroj opterećenja svih lijevih kotača 49,4 %, što ukazuje da je točka težišta forvardera zanemarivo pomaknuta od uzdužne simetrale vozila u desnu stranu.

Uspoređujući dimenzijske i masene značajke forvardera Komatsu 875 sa rezultatima morfološke analize forvardera (Horvat i dr. 2004), može se zaključiti da se on uklapa u konstrukcijske zakonitosti ovodobnih forvardera.

Plan raspodjele tereta forvardera Komatsu 875 (slika 8), napravljen je korištenjem izraza 1 – 6, na osnovi: međuosovinskog razmaka (5,375 m), udaljenosti uzglavlja utovarnog prostora od prednje osovine (2,9 m), 21,385 t neto mase i njene raspodjele na prednju (12,718 t) i stražnju (8,667 t) osovinu, deklarirane nosivosti od 16 t, dopuštenih osovinskih opterećenja pneumatika kotača prednje (22,4 t) i stražnje (27,6 t) bogi osovine.

Na dobrotu konstrukcije (dimenzijskih i masenih značajki) forvardera Komatsu 875 uz popunjenost poprečnoga presjeka utovarnoga prostora (4,75 m^2) i njegovo iskorištenje od 70 %, ukazuju spoznaje iščitane iz dijagrama slike 7: 1) forvarder je dimenzioniran za tvrde listače (1000 kg/m^3) jer

dosiže deklariranu nosivost pri utovaru oblovine duljine od 4,82 m, koja je malo veća od duljine utovarnoga prostora (4,726 m), 2) pri utovaru četinjača (850 kg/m^3)[1], deklarirana nosivost forvardera će se dosegnuti kod utovara oblovine duljine od 5,65 m, 3) pri navedenim duljinama utovarenoga drva tvrdih listača i četinjača kriteriji preopterećenja prednje i stražnje osovine, preopterećenja pneumatika, kao i rasterećenja prednje osovine neće ograničavati deklariranu nosivost forvardera. Pri planiranju izvoženja drva, navedene duljine tvrdih listača i četinjača treba poimati kao prosječne vrijednosti duljine sortimenata u cilju dosezanja što veće proizvodnosti forvardera.

5. RASPRAVA
DISSCUSION

Vezano za dimenzijske i masene značajke forvardera, rasprava je napisana kroz osvte na normu ISO 13860 (2016) te KWF-ov plan raspodjele tereta forvardera, odnosno ocjenu dobrote forvardera Komatsu 875.

Norma ISO 13860 (2016) odnosi se samo na kotačne forvardere, dok izrijekom ne spominje: 1) gusjenične forvardere te 2) niti jedan od pokazatelja forvardera opremljenih sidreno-trakcijskim užem za rad na strmim terenima (npr. zakretna samonivelirajuća kabina). Isto tako, ne spominje, niti preporuča izraz za procjenu dodirnih tlakova natovarenoga forvardera na šumsko tlo. Zbog velikog utjecaja dodirnih tlakova forvardera na šumsko tlo, kao pokazatelj okolišne pogodnosti forvardera valjalo bi u normu uključiti nominalni tlak na podlogu (Melgren 1980) zbog jednostavnosti njegovog izračuna, ali i prihvaćenosti od strane šumarskih stručnjaka (Partington i Ryans 2010, Poršinsky i dr. 2011, Nordfjell i dr. 2019).

Od dimenzijskih značajki forvardera, norma ISO 13860 (2016) izrijekom ne poznaje: 1) duljinu i visinu prednjeg i stražnjeg prepusta forvardera, 2) kutove prohodnosti forvardera, 3) polumjere prohodnosti forvardera, koje poneki proizvođači iskazuju u svojim prospektnim materijalima ili atestne organizacije u svojim izvješćima. Na primjeru skidera s vitlom, Poršinsky i dr. (2016) pojašnjavaju značenje te način izračuna navedenih pokazatelja prohodnosti šumskih vozila.

Zbog položaja kotača stražnje bogi osovine forvardera, poprečni presjek utovarnog prostora forvardera (slika 3E) složeni je geometrijski lik koji se sastoji od jednakokračnoga trapeza (manji doljnji dio) i pravokutnika (veći gornji dio). Norma ISO 13860 (2016) ne poznaje sve dimenzije ovih geometrijskih likova potrebne za izračun poprečnega presjeka utovarnoga prostora forvardera, a koje su za forvarder Komatsu 875 prikazane na slici 5. Iako norma poznaje visinu težišta tereta (hh_8 – slika 3E), ne objašnjava način izračuna ovoga pokazatelja, a koji se izračunava putem visine težišta dijela poprečnog presjeka koji se odnosi jednakokračni trapez, odnosno pravokutnik uz korištenje izraza momenta površine.

Osim navedenih dimenzijskih značajki, norma ISO 13860 (2016) ne poznaje udaljenost uzglavlja utovarnoga prostora forvardera od prednje osovine vozila, a koja se ne može niti izračunati iz normom određenih dimenzija forvadera (slika 3A), a ulazni je parametar izračuna Plan raspodjele tereta forvardera (Weise 2002).

Najznačajniju masenu značajku – položaj točke težišta nenatovarenoga forvardera na horizontalnoj podlozi, norma ISO 13860 (2016) ne poznaje, niti ju iskazuju proizvođači forvardera. Težište vozila je bitan konstruktivni pokazatelj, koji ima velik utjecaj na vučnu značajku i stabilnost kretanja vozila, a predstavlja točku u kojoj je koncentrirana cjelokupna masa vozila. Uz pretpostavku da se točka težišta nalazi na uzdužnoj simetrali vozila, određena je: 1) horizontalnom udaljenošću od prednje osovine, 2) horizontalnom udaljenošću od stražnje osovine te 3) visinom od horizontalne podloge. Uslijed manjih brzina kretanja šumskih vozila u odnosu na cestovna, položaj težišta forvardera je statička, u osnovi nepromjenjiva značajka, koja se dinamički ne mijenja pri ubrzanju, kočenju ili kretanju u krivinama. Zbog sve većeg korištenja forvardera na nagnutim terenima (Marčeta i dr. 2020, Mederski i dr. 2021, Borz i dr. 2021, Ring i dr. 2021), ovaj maseni pokazatelj forvardera dobiva na značenju zbog njegove neophodnosti pri modeliranju raspodjele osovinskih opterećenja i dodirnih tlakova te kretnosti šumskih vozila s obzirom na uzdužni nagib terena i smjer kretanja (Đuka i dr. 2016, Đuka i dr. 2018, Poršinsky i dr. 2021) u cilju planiranja privlačenja drva na siguran, djelotvoran i okolišno prihvatljiv način.

Plan raspodjele tereta forvardera izuzetno je dobar brzi alat za ocjenu dobrote konstrukcije forvardera prilikom njihove nabave, kao i pomoći krajnjim korisnicima pri planiranju izvoženja drva te je svoje mjesto našao u KWF-im izvješćima (eng. *Test report*, njem. *Prüfbericht*) o forvarderima (Hauck 2002). Od ulaznih parametara potrebnih za izračun preopterećenja prednje i stražnje osovine forvardera, proizvođači u prospektnim materijalima ne iskazuju dopuštena osovinska opterećenja forvardera koja bi u sklopu nabavke forvardera trebalo dodatno zatražiti. Najmanje opterećenje prednje osovine forvardera od 20 % mase opterećenoga forvardera, dobro je odabran kriterij rasterećenja prednje osovine potreban radi zadržavanja upravljivosti forvarderom. Isti kriterij kod skidera s vitlom, Sever (1990) određuje kao najmanji odnos adhezijskog opterećenja prednje i stražnje osovine skidera pri vuči drva na nagnutim terenima ($G_1 : G_2 > 1 : 3{,}5$). Ostale Pretpostavke izračuna mase utovarenoga drva (gustoća drva tvrdih listača od 1000 kg/m^3

[1] Istraživanja provedena na četinjačama u Hrvatskoj (Sinković 1991) ukazuju na gustoću drva četinjača od 850 kg/m^3.

te četinjača od 700 kg/m^3, iskorištenost/popunjenost poprečnoga presjeka utovarnoga prostora od 70 %), lako je modificirati s obzirom na lokalne prilike. Poršinsky i dr. (2014) istražujući proizvodnost izvoženja drva forvarderima s obzirom na propisnost mjerenja drva, na primjeru forvardera Valmet 840.2 utvrđuju gustoću hrasta lužnjaka od 992 do 998 kg/m^3 bruto obujma utovarenoga drva, a iskorištenje je poprečnog presjeka utovarnoga prostora imalo vrijednosti: 65 % pri utovaru trupaca i višemetarskog ogrijevnog drva, 72 % pri utovaru višemetarskog ogrijevnog drva, odnosno 75 % pri utovaru trupaca.

Na osnovi izmjere dimenzijskih i masenih značajki forvardera Komatsu 875, može se zaključiti da on udovoljava svim dimenzijskim i masenim zakonitostima konstrukcije ovodobnih forvardera (Horvat i dr. 2004, Nordfjell i dr. 2010, Nordfjell i dr. 2019). Navedeno potvrđuje i Plan raspodjele tereta forvardera Komatsu 875, koji ukazuje da kriteriji preopterećenja prednje i stražnje osovine, preopterećenje pneumatika te rasterećenja prednje osovine ne ograničavaju dosezanje od strane proizvođača deklarirane nosivosti pri izvoženju drva tvrdih listača i četinjača.

Na kraju diskusije, treba istaknuti da konačni sud o nabavci forvardera treba donijeti i na osnovi istraživanja njegove proizvodnosti (Stankić i dr. 2012, Gagliardi i dr. 2020, Borz i dr. 2021, Kymäläinen i dr. 2021, Spinelli i dr. 2021), odnosno troškovnih analiza (Naderializadeh i dr. 2020, Triplat i dr. 2020, Abbas i dr. 2021, Sessions i dr. 2021).

6. UMJESTO ZAKLJUČKA
INSTEAD OF CONCLUSION

U prospektnim materijalima proizvođača forvardera dostupno je svega nekoliko njihovih dimenzijskih i masenih značajki (u odnosu na one koje poznaje norma ISO 13860 ili neke druge značajke koje dodatno opisuju prohodnost šumskih vozila), a na osnovi kojih krajnji korisnici donose sud pri odabiru/nabavci vozila. Vrlo često je prilikom nabavke forvardera presudna nabavna cijena te uvjeti postprodaje poput dostupnosti servisa, odnosno cijena i brzina isporuke rezervnih dijelova.

Teško je reći koje su dimenzijske i masene značajke ključne za odabir/nabavu forvardera, jer su mnoge od njih u međudjelovanju, ali i sve nemaju isto značenje s obzirom na radne uvjete koji prevladavaju na području krajnjega korisnika. Stoga je od proizvođača potrebno zatražiti dodatne dimenzijske i masene pokazatelje forvardera, s obzirom na prevladavajuće terenske i sastojinske čimbenike ciljanoga područja rada krajnjega korisnika.

Na dimenzijskim i masenim značajkama se zasniva i Plan raspodjele tereta forvardera, koji predstavlja jednostavan i brz alat ocjene dobrote konstrukcije forvardera sa ciljem utvrđivanja mogućnosti dosezanja deklarirane nosivosti forvardera, uz uvažavanje kriterija preopterećenja prednje i stražnje osovine te rasterećenja prednje osovine. Navedeno osigurava sigurno i djelotvorno izvoženje drva forvarderom, ali i otklanjanja mogućih oštećenja forvardera u njihovome uporabnom ili amortizacijskom razdoblju. Njemački KWF, određuje za forvarder ukupno vrijeme uporabe 10 godina ili 16.000 (14.000 – 18.000) pogonskih sati, odnosno razdoblje amortizacije od 7 godina ili 11.200 pogonskih sati (Forbig i Büttner 2013).

Zbog sve učestalijeg korištenja forvardera na terenima s određenim stupnjem nagiba, poseban će mjeriteljski izazov predstavljati određivanje točke težišta forvardera sa ciljem modeliranja kretnosti forvardera s obzirom na smjer izvoženja drva i uzdužni nagib terena u svrhu planiranja pridobivanja drva.

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SUMMARY

Timber forwarding is characterised by carrying timber clear of the ground and loading timber assortments by a hydraulic crane, which results in the requirement for a parallel network of secondary forest infrastructure network where the distance between trails equals to double span of the hydraulic crane.

The paper presents 1) dimensional and mass characteristics of forwarders considering ISO 13860 (2016) standard and 2) forwarder load distribution plan developed by the German Kuratorium für Wadarbeit und Forsttechnik (KWF) to assist forestry experts in the purchase and use of these forest vehicles.

The heavy eight-wheel forwarder Komatsu 875 was selected as an example. Its dimensional and mass characteristics are shown based on measurements and the load distribution plan, aiming to evaluate the vehicle.

A critical comment is also given regarding the ISO 13860 (2016) standard due to the lack of some dimensional (length and height of the front and rear overhangs of forwarders, approach and departure angles and clearance radii) and mass (position of the centre of gravity point) of forwarders. These characteristics describe and serve to model its mobility during timber forwarding concerning the direction and longitudinal slope of the terrain. In addition, the ISO 13860 (2016) standard does not explicitly mention any indicator of environmental suitability (e.g. nominal ground pressure).

KEY WORDS: mobility and performance characteristics of forwarders, ISO 13860 (2016), load distribution

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FACTORS OF NATURAL REGENERATION OF *Platycladus orientalis* (L.) FRANCO IN GUILIN, CHINA

ČIMBENIK PRIRODNE OBNOVE VRSTE *Platycladus orientalis* (L.) FRANCO U GUILINU, KINA

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SUMMARY

Cypress (*Platycladus orientalis* (L.) Franco) is one of the important evergreen trees for afforestation in barren mountains, soil consolidation, and water conservation, but natural regeneration of cypress is complex and slow. An understanding of the influence mechanism of the natural regeneration of cypresses is essential for elevating survival and regeneration. This study aimed to clarify the relationship between stand factors, environmental factors, and regeneration of cypress plantations. A total of 42 cypress sample plots in Guilin, China, were selected to evaluate the impact of various stand factors and environmental factors on the regeneration of cypresses using survey statistics and Pearson and Spearmanrank correlation analysis. In this study, cypress has the highest frequency and density of regeneration among all the seedlings in the 18 surveyed forests, but the height structure of cypress seedlings distributes in uneven mode and mainly Grade I (height < 30 cm) seedlings. Low-density herbs and high-density moss mulching had a directly positive effect on the number of cypress regeneration seedlings. Larger soil stone content and gap area can promote cypress regeneration, which is appropriate for cypresses in the seedling stage. In conclusion, timely weeding, proper soil loosening, and improving light transmittance contribute to promoting the regeneration of cypresses.

KEY WORDS: Cypress; Stand factors; Environmental factors; Natural regeneration.

INTRODUCTION
UVOD

Natural regeneration (NR) refers to the process where forests are reformed entirely relying on natural forces (Chazdon and Guariguata 2016; Khaine et al.2018 ;Ribeiro et al. 2022). As an important and complex ecological process, the NR of forests is always one of the main fields of research of forest management and ecosystem, which has an important impact on vegetation development and ecosystem. In recent years, to clarify the influential factors of NR of plants, scholars have made great efforts in terms of environmental factors such as seed characteristics, stand factors, soil factors, habitat factors, and interference factors. For instance, seedling establishment is not only the initial stage of controlling forest dynamic development but also an important stage. Microhabitat greatly affects seedling establishment

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(Efimenko and Aleinikov 2019; Noguchi et al. 2011). Madsen reported that under the open canopy (13% light) or closed canopy (5% light), fertilized and irrigated in a mineral soil seedbed have different effects on seedling growth of beech (*Fagus sylvatica*), and weed competition did not significantly reduce seedling growth (Madsen 1995). These implicated that light intensity, soil water content and nutrient supply effect on natural regeneration of beech. In turn, NR also improves soil fertility, microbial biomass carbon and enzyme activity more than artificial afforestation (Hu et al. 2020; Pang et al. 2018) and also alters compositional and functional shifts in soil seed banks(Medeiros-Sarmento et al. 2021). Additionally, the characteristics of forest gaps have an important impact on light environment, temperature and humidity and micro terrain, and play an important role in forest regeneration, for example, number of beech increased with gap size and light availability; and herbaceous species abundance also significantly effected by gap size (Naaf and Wulf 2007; Qin et al. 2011). These studies have shown that the efficiency of NR is affected by environmental factors.

Additionally, the stand factor is another regulatory factor that affects the frequency of NR. For example, in forests, gaps of different sizes and ages have different effects on tree density, dominance, the conversion rate from seedlings to young trees, and spatial pattern of seedlings and young trees (Ugarković et al. 2018; Zhu et al. 2014), which significantly affects the growth of regeneration seedlings (Beckage and Clark 2003). Different shade-tolerant tree species also have certain segmentation in the utility of forest gap ecological resources (Ugarković et al. 2018). In addition, natural forest regeneration is also affected by some special habitats, such as karst scar habitat (Gholami et al. 2018). Studied found that the special habitat of karst scar (except the dissolution corridor) in the karst area can preserve some plant residues and provide a source of propagules for plant regeneration (Hu et al. 2020; Pang et al. 2018). Bryophyte communities affect seed dispersal, seed germination, and seedlings establishment, and also exert a role of the allelopathy on vascular plants (Fukasawa et al. 2019).

Platycladus orientalis (L.) Franco (cypress) is an evergreen tree species of the cypress family. Cypress likeswarm and humid climate conditions and has wide adaptability to soil including neutral, slightly acidic and calcareous soil, and particularly prefers the shallow calcareous purple soil and lime soil in the upper layer. Cypress needs sufficient upper light to grow, but they also have a certain resistance to shadein the seedling stage. Cypress can play an important role in the ecological construction of arid and barren forests in mountainous areas. However, the natural NR of cypress plantations used for ecological construction is very difficult, which greatly reduces the efficiency of ecological improvement (Kimambo and Naughton-Treves 2019). Importantly, in cases where cypress dominated forest is aimed/auchtonus forest type, the weakness of NR ability of cypress plantation significantly affects the stability of the ecosystem, which is not conducive to sustainable management. At present, it is known that the NR of cypress plantations is the result of a comprehensive restrictions of many factors. For example, the regeneration of Arizona cypress affected by wildfire (Dos Santos et al. 2019). Cypress seedlings can grow in large numbers due to the release of seeds from serous cones, the exposure of mineral soil, and the increase of solar radiation (Barton and Poulos 2018). Proper thinning intensity can achieve a better regeneration effect of cypress (Olson et al. 2014). Different stand densities, soil water content, and litter cover thickness significantly impact on seed germination and early seedling growth (Islam et al. 2016). However, there is no research on the environmental factors and stand factors limiting cypress regeneration, thus,the strategies for managing and promoting the natural regeneration of cypress plantations are not yet fully understood.

As far as we know, the effect of environmental factors and stand factors on cypress regeneration is studied for the first time. In this study, we aimed to explore (1) whether cypress can regenerate naturally; (2) which factors affect NR of cypresses; and (3) how these factors affected NR of cypresses. This study provides an empirical basis for the management and the promotion of NR for cypress plantations.

METHODS
METODE

Overview of the study area – *Pregled područja istraživanja*

This study was conducted in Guilin city, located in the Southwest of Guangxi, China (latitude 24° 55' – 25° 18', longitude 110 ° 18' – 110 ° 45', altitude 115–421 m) (Figure 1). Cypress is one of the major species of artificial vegetation in this area and is mostly distributed in the middle and lower part of the mountains. The climate of the survey region is the subtropical monsoon climate with the characteristic of a mild climate, abundant rainfall, long frost-free period, sufficient light, abundant heat, long summer and short winter, four distinct seasons, and the same season of rain and heat. The climatic condition of survey region is superior with less snow in three winters and frequent flowers in four seasons. The annual average temperature is around 19.4 °C, July and August are the hottest months of the year with an average temperature of about 28.5 °C; January and February are the coldest months of the year with an average temperature of about 8.3 °C. The annual average frost-free period is 309 days, the annual average rainfall is 1974 mm, and the annual average relative humidity is

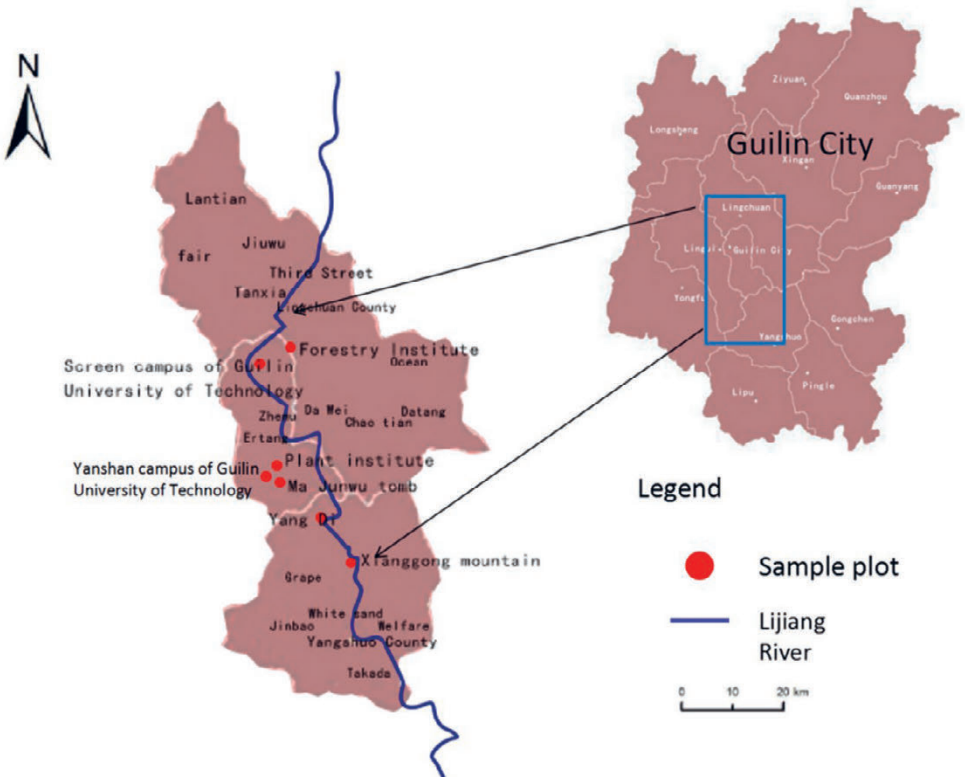

Figure 1. Area map of 42 sample plots in 7 area in China.
Slika 1. Karta područja prikazuje 42 uzorka uzetih s ploha sa 7 područja u Kini.

73–79%. The annual wind direction is mainly northerly with an average wind speed of 2.2–2.7 m/s. The annual average sunshine time is 1670 h and the average air pressure is 994.9 hPa. The soil of the selected survey area is mainly calcareous.

The desired position of Figure 1.

Introduction of influencing factors – *Uvod u čimbenike utjecaja*

This study was conducted from July to October 2020 and from May to June 2021 within 7 regions, and each region set up 6 duplicate sites thus a total of 42 study plots of cypress forests, and each plot is a square with 10 m × 10 m.

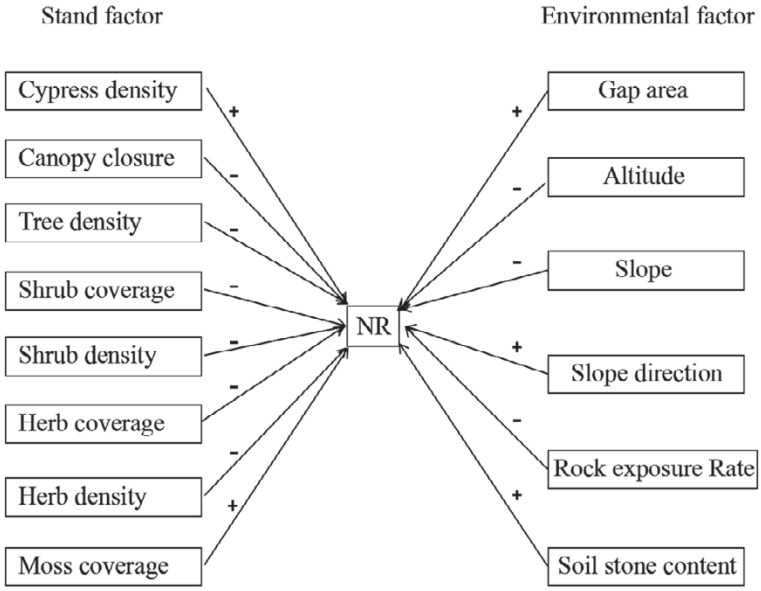

Figure 2. Hypothesis on influencing factors of NR of cypress plantation. Note: + represents positive correlation; - represents negative correlation.
Slika 2. Hipoteza o utjecaju čimbenika prirodne obnove nasada obične azijske tuje Napomena: + predstavlja pozitivnu korelaciju; - predstavlja negativnu korelaciju.

Each plot is at least 50 m apart so that they have different ecological conditions. Therefore, plots could be served as single observations.In each plot of cypress forests, the team investigated the regeneration characteristics, stand factors (biological factors) and environmental factors (abiotic factors). The recorded characteristics of natural regeneration mainly included species, quantities, and tree heights of regeneration plants; stand factors of records mainly include adult cypress density, tree canopy density, tree density, shrub coverage, shrub density, herb coverage, herb density, and moss coverage; environmental factors of records mainly include long and short axis length of forest gap, altitude, geographical coordinates, slope, slope direction, rock exposure rate, and soil stone content.

Establishment of a model for influence factor of NR of cypress plantation – *Utvrđivanje modela za utjecaj čimbenika prirodne obnove (NR) na plantaži obične azijske tuje*

According to the principles of objectivity, representativeness, systematicness, and measurability, and based on the investigation analysis, our study constructed an influence factor model of NR of cypress plantation, which was composed of stand factors and environmental factors, as shown in Figure 2.

The desired position of Figure 2.

Division standard of regeneration seedlings – *Distribucija pomlatka prema visinskim klasama*

An age structure is an important characteristic of population dynamics. The height level of seedlings can be used to replace an age structure in seedling research. In this study, cypress seedlings were divided into four grades based on plant height level (Table 1).

The desired position of Table 1.

Data analysis – *Analiza podataka*

The data of characteristics stand factors and environmental factors of regeneration seedling in the sample plots were pre-processed. Slope direction management: In each plot of cypress forest, the fixed slope direction is 0° to the north and the slope direction gradually increases clockwise, thereby 0 ~ 45° and 315° ~ 360° are shady slopes; 45° ~ 135° is semi shady slope; 135° ~ 225° is sunny slope; 225° ~ 315° is semi sunny slope.

Gap measurement: In each plot of cypress forest, gap area was calculated by the elliptic area formula: $S = \pi AB / 4$ (where S was the forest gap area, A was the long axis length and B was the short axis length).

Statistical analysis: All data analysis was completed by GraphPad Prism v9 software. Data were subjected to a non-parametric test using Kruskal-Wallis.Pearson and Spearmanrank correlation test was used for correlation analysis. Multiple stepwise regression analysis was used to explore which stand factors and environmental factors had an impact on regeneration. $P < 0.05$ was considered statistically significant.

RESULTS
REZULTATI

Density structure of regeneration seedlings – *Gustoća sklopa pomlatka*

he study plots were located in pure cypress forest or mixed forest, with the characteristics of altitude of 149 – 348 m. The community structure of survey area was complete with arbor, shrub and grass, and plant species was abundant. See Table 2 for the main types of trees and shrubs and all types of regeneration seedlings in the survey area.

The desired position of Table 2.

In 42 investigated plots, the distribution of cypress regeneration seedlings and plants was extremely uneven. The regeneration density of one plot (No.8 plot) was up to 48000 ~ 49000 individuals / hm^2, and we also found that the moss coverage of this sample plot was very high and the forest gap area was large. The density of regeneration seedlings in other sample plots was concentrated at 1–8000 individuals / hm^2, as shown in Table 2. However, plant density of regenerated seedlings in 20 sample plots was 0 individuals / hm^2, meaning no regeneration phenomenon. Additionally, the average regeneration density of 22 sample plots with cypress seedlings was calculated, as 5018 individuals / hm^2. In general, the number of regenerations of cypress in some sample plots was large and small in some sample plots, and the density and regeneration frequency of cypress plantation in the survey plots still have room for improvement.

The desired position of Table 3.

Table 1. Classification criteria of seedlings and young trees
Tablica 1. Kriteriji klasiranja sadnica i mladih stabala

Grade *Sadnica*	Grade I Seedling *Sadnica I klase*	Grade II Seedling *Sadnica II klase*	Grade III young tree Mlado stablo *III klase*	Grade IV young tree *Mlado stablo IV klase*
Standard *Standard*	H<30 cm	30 cm≤H<60 cm	60 cm≤H<100 cm	H≥100 cm and DBH<5 cm

Table 2. Table of main tree and shrub species and all regeneration seedling species in the survey area

Common Name	Scientific Name
Main plant species in the survey area	
Cypress	
Melia azedarach	Melia Azedarach
Choerospondias axillaris	Choerospondias axillaris (Roxb.) Burtt et Hill.
Berry neem	Cipadessa baccifera (Roth.) Miq.
Jade leaf golden flower	Mussaenda pubescens W. T. Aiton
Alchornea trewioides	Alchornea trewioides (Benth.) Muell. Arg.
Paper mulberry	Broussonetia Papyrifera (Linn.) L'Hér. ex Vent.
Cuiyun grass	(Selaginella uncinata (Desv.) Spring
Sedge	Carex brunnea Thunb.
Southern brocade moss	Brotherella henonii (Duby) Fleisch
Setaria plicata	Setaria plicata (Lam.) T. Cooke
Seedling species recorded in the sample plot	
Cypress	
Berry neem	
Jade leaf golden flower	
Broussonetia papyrifera and Camphor	Cinnamomum camphora (L.) J. Presl
Pepper tree	Zanthoxylum bungeanum Maxim.
Purple brocade	Euphorbia cotinifolia Miq.
Rhamnus	Rhamnus davurica Pall.
Rhus chinensis	Rhus chinensis var. Roxburghii (DC.) Rehder
Wild pepper	Lindera glauca var. Nitidula Lecomte
Maclura tricuspidata	Maclura tricuspidata Carrière
White catalpa	Mallotus paniculatus (Lam.) Müll. Arg.
Eucalyptus	Eucalyptus robusta Sm.
Star anise maple	Alangium chinense (Lour.) Harms
Yellow cow wood	Cratoxylum cochinchinense (Lour.) Blume
Cassia tree	Cinnamomum japonicum Siebold
Toona sinensis	Toona sinensis (Juss.) Roem.
Sweet-scented osmanthus	(Osmanthus fragrans (Thunb.) Lour.
Eurya	Eurya japonica Thunberg
Mulberry	(Morus alba L

Height structure of regeneration seedlings – *Visinska struktura prirodnog pomlatka*

In the investigated plots, cypress seedlings were only observed in 22 sample plots, of which sample plot No.8was very specialin that the number of renewed seedlings was much higher than that in other sample plots. To reduce the experimental error, sample plot No.8 with maximum value was removed when analyzing the height structure of seedlings at all levels. Although cypress seedlings appeared in plot 23, plot 26, and plot 28, grade I seedlings were lacking, that is, cypress seedlings in these three plots were planted manually. To reduce the experimental error, these three plots were also not involved in the analysis. Therefore, only remaining 18 sample plots were involved in the analysis of the height distribution of cypress seedlings.

Table 3. Distribution of NR seedling density of cypress
Tablica 3. Distribucija NR gustoće sadnica obične azijske tuje.

Renewal density (individuals / hm^2) *Broj pomlatka po (pojedinačno / hm^2)*	Number of sample plots *Broj uzorkovanih ploha*
0	20
1-1000	5
1001-2000	6
2001-3000	2
3001-4000	2
4001-5000	2
5001-6000	1
6001-7000	1
7001-8000	2
48000-49000	1

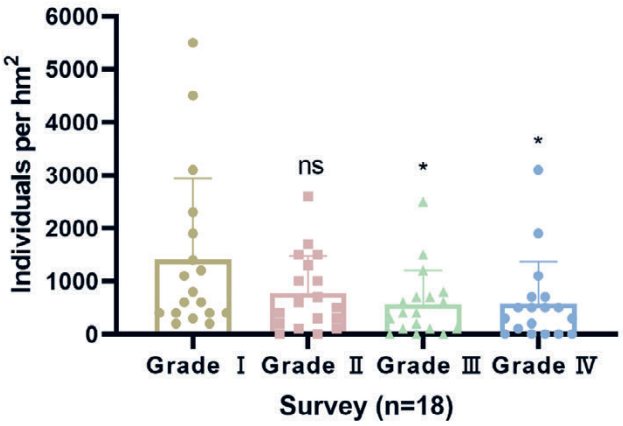

Figure 3. Height class structure of cypress regeneration seedlings. * represents $P < 0.05$, ns represents $P > 0.05$.
Slika 3. Visinska struktura pomlatka obične azijske tuje. * predstavlja $P < 0,05$, ns predstavlja $P > 0,05$.

As shown in Figure 3, the results showed that there were significant differences in the number of seedlings between grade I and grade III or IV young trees. The height structure of cypress regeneration seedlings showed a skewed distribution, and the numbers of cypress regeneration seedlings decreased with grades. The number of Grade I seedlings was the largest, suggesting that the seeds successfully germinated to form seedlings, and cypresses have no germination obstacles. The number of Grade I, Grade II, Grade III, and Grade IV showed a decreasing trend.

The desired position of Figure 3.

Cypress regeneration effected by stand factors especially herb coverage and moss coverage – *Na prirodnu obnovu obične azijske tuje utječu sastojinski čimbenici, posebice pokrovnost biljem i mahovinom*

To explore the impact of stand factors on the NR of cypress, the correlation analysis between stand factors and cypress regeneration seedlings was carried out (Table 4). The results showed that there was a significant negative correlation between herb density and regeneration density. In addition, a significant positive correlation between moss coverage and seedlings of all grades and renewal density was observed (Table 4). However, no significant correlation between other parameters and cypress regeneration seedlings could be observed (Table 4, Figure 4). For example, although cypress density is a reason for affecting the number of seeds under the forest, cypress regeneration seedlings showed no direct or significant correlation with the number and density, indicating that there are sufficient provenances in the sample plot, and provenance is not the main factor affecting cypress regeneration.

The desired position of Table 4.

The desired position of Figure 4.

Stepwise multiple regression analysis was carried out on 8 stand factors,including cypress density, canopy density, tree density, shrub coverage, shrub density, herb coverage, herb density, and moss coverage, to analyze the factors that may affect NR of cypress (Table 5). As a result, the model eliminated 6 variables, while the herb coverage and moss coverage were retained. The optimal regression equation was composed of herb coverage and moss coverage, as follows: RD = –6467.345 + 194.074 * MC + 101.769 * HC. (RD represents renewal density; MC represents moss coverage; HC indicates herb coverage)

The results showed that the regeneration density of cypress was mainly affected by two factors: herb coverage and moss coverage. Adjusting the determination coefficient R^2 to 0.37 showed that these two variables could partially determine the regeneration density of cypress. In short, high-density of herb was unfavorable to cypress regeneration while high moss coverage was contrary.

The desired position of Table 5.

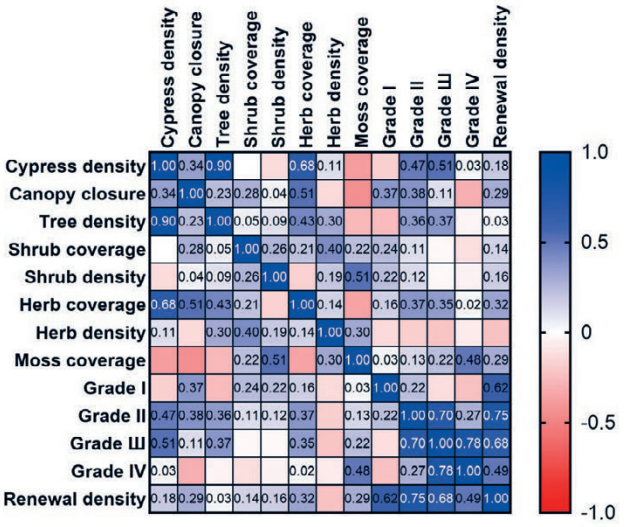

Figure 4. Pearson's correlation coefficient heatmap between stand factors and the number of cypress regeneration seedlings.
Slika 4. Toplinska karta Pearsonovog koeficijenta korelacije između sastojinskih čimbenika i pomlatka obične azijske tuje.

Table 4. Spearman correlation between stand factors and the number of cypress regeneration seedlings
Tablica 4. Spearmanova korelacija između čimbenika sastojine i broja regeneracijskih sadnica obične azijske tuje

Stand factor *Sastojinski* čimbenici	Grade I *Klasa I*	Grade II *Klasa II*	Grade III *Klasa III*	Grade IV *Klasa IV*	Renewal density *Gustoća pomlatka*
Cypress density *Gustoća obična azijska tuja*	0.086	0.004	-0.056	-0.119	0.034
Canopy closure *Sastojinski sklop*	-0.071	-0.104	-0.102	-0.209	-0.034
Tree density *Gustoća stabala*	-0.034	0.031	0.096	-0.075	0.002
Shrub coverage *Pokrovnost grmlja*	0.017	-0.114	0.003	-0.004	0.01
Shrub density *Gustoća grmlja*	0.138	0.133	0.044	0.061	0.084
Herb coverage *Pokrovnost bilja*	-0.276	-0.198	-0.231	-0.283	-0.267
Herb density *Gustoća bilja*	-0.222	-0.276	-0.292	-0.283	-.310*
Moss coverage *Pokrovnost mahovinom*	.647**	.666**	.662**	.718**	.708**

Note: * and ** denote significance level at $P < 0.05$ and $P < 0.01$, respectively.
*Napomena: * i ** označavaju razinu značajnosti pri $P < 0,05$ i $P < 0,01$.*

Table 5. Multiple regression model of cypress regeneration density and stand factors
Tablica 5. Višestruki regresijski model za gustoću prirodnog pomlatka i stanišnih čimbenika

	B	β	t	P
Constant term *Stalno*	-6467.345		-2.72	0.01
Moss coverage *Pokrovnost mahovinom*	194.074	0.63	4.867	0
Herb coverage *Pokrovnost biljem*	101.769	0.374	2.887	0.006

Cypress regeneration effected by environmental factors especially soil stone content, slope direction, and forest gap area – *Na prirodnu obnovu obične azijske tuje utječu ekološki čimbenici, posebice sadržaj kamena u tlu, ekspozicija i površina otvora (gapova)*

We next explore the effect of environmental factors on cypress regeneration. The correlation analysis between various components of environmental factors and the number of cypress regeneration seedlings showed that the number of cypress regeneration seedlings was significantly positively correlated with soil stone content, slope direction, and forest gap area, but not with other environmental factors (Table 6; Figure 5). The number of cypress regeneration seedlings for level I-III and renewal density were significantly positively correlated with soil stone content. Cypress renewal density and the height of cypress seedlings at all levels were positively correlated with slope direction (Table 6; Figure 5). We also observed a significantly positive correlation between the number of cypress seedlings of all grades and renewal density and forest gap area (Table 6; Figure 5).

The desired position of Table 6.

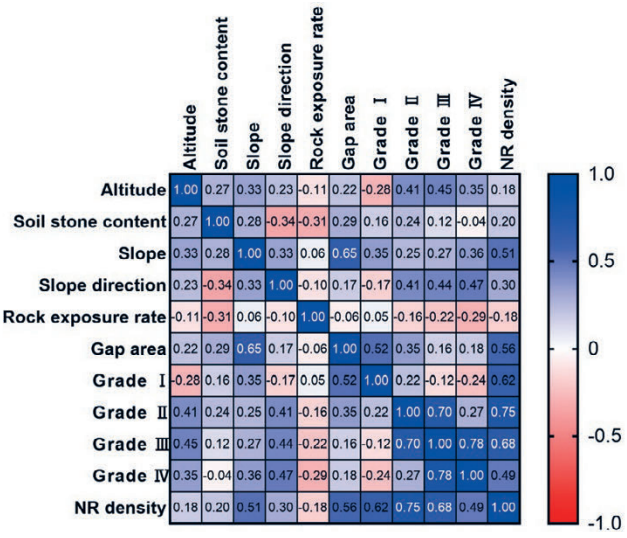

Figure 5. Pearson's correlation coefficient heatmap between environmental factors and the number of cypress regeneration seedlings.
Slika 5. Toplinska karta Pearsonovog koeficijenta korelacije između ekoloških čimbenika i pomlatka obične azijske tuje.

The desired position of Figure 5.

Multiple stepwise regression analysis was carried out between cypress regeneration density and six environmental factors, such as altitude, soil stone content, slope, slope direction, rock exposure rate, and forest gap area,to analyze the factors that may affect NR of cypress (Table 6). The results showed that the model excluded four variables including altitude, slope, slope direction, and rock exposure rate, and established a model based on soil stone content and gap area. The optimal regression equation was composed of two variables as follows:

RD = –2030.644 + GA * 295.61 + 223.517 * SSC. (RD represents renewal density; GA represents forest gap area; SSC is the soil stone content)

Table 6. Spearman correlation between environmental factors and the number of cypress regeneration seedlings
Tablica 6. Spearmanova korelacija između ekoloških čimbenika broja prirodnog pomlatka obične azijske tuje

Environmental factor *Ekološki čimbenici*	Grade I *Klasa I*	Grade II *Klasa II*	Grade III *Klasa III*	Grade IV *Klasa IV*	Renewal density *Gustoća pomlatka*
Altitude *Nadmorska visina*	0.054	0.259	0.248	0.288	0.17
Soil stone content *Sadržaj kamena u tlu*	.477**	.339*	.310*	0.25	.384*
Slope *Nagib*	0.122	0.239	0.288	0.304	0.22
Slope direction *Ekspozicija*	.384*	.551**	.574**	.514**	.530**
Rock exposure rate *Stupanj kamenitosti*	-0.067	-0.022	0.034	0.047	-0.011
Gap area *Površina otvora*	.742**	.695**	.646**	.662**	.755**

Note: * and ** denote significant difference at $P < 0.05$ and $P < 0.01$, respectively.
*Napomena: * i ** označavaju značajnu razliku pri $P < 0,05$ i $P < 0,01$.*

Table 7. Multiple regression model between cypress regeneration density and environmental factors
Tablica 7. Model višestruke regresije između gustoće prirodnog pomlatka obične azijske tuje i ekoloških čimbenika

	B	b	t	P
Constant term *Stalno*	-2030.644		-2.642	0.012
Soil stone content *Sadržaj kamena u tlu*	295.61	0.621	5.459	0
Gap area *Površina otvora*	223.517	0.307	2.697	0.01

The results showed that the regeneration density of cypress was mainly affected by soil stone content and forest gap area. Adjusting the determination coefficient R^2 to 0.739 showed that these two variables could determine the regeneration density of cypress to a higher extent. Taken together, soil stone content, slope direction, and forest gap area were important environmental factors for promoting cypress regeneration.

The desired position of Table 7.

Subsequently, to further explore the effects of soil stone content, slope direction, and forest gap area on cypress regeneration, we respectively analyzed the correlation between their and the number of cypress seedlings. As shown in Table 7, the number of cypress regeneration seedlings showed an upward trend with the increase of soil stone content. The soil of the sample plot contains a lot of gravel, and the gravel is evenly distributed in the soil (Table 7).

The desired position of Table 8.

We also analyzed the effect of slope direction on cypress regeneration seedlings in 18 sample plots with cypress regeneration (Figure 6). The regeneration capacity of regenerated cypress seedlings with different slope directions was ranked as follows: shady slope > semi shady slope > sunny slope > semi sunny slope. There was no significant difference in the number of grade I seedlings on the four slopes, but significantly different between the grade II seedlings on the shady slope and the sunny and semi sunny slope were observed. The number of grade III seedlings on shady slope was significantly different from the other three slope directions. The difference results of the grade IV seedlings were the same as those of the grade II seedlings (Figure 6).

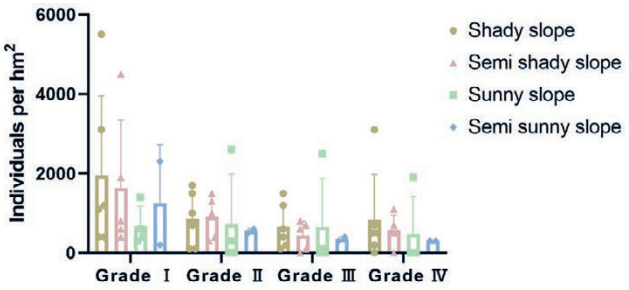

Figure 6. Number of renewal seedlings in different slope directions.
Slika 6. Broj sadnica iz prirodne obnove na različitim ekspozicijama.

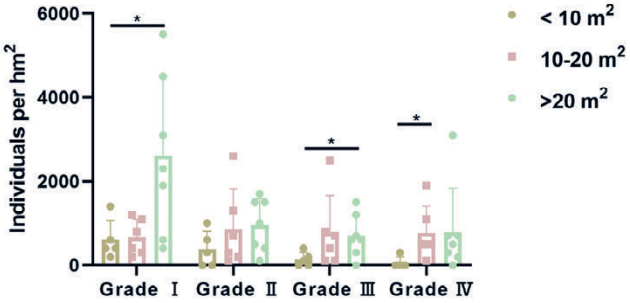

Figure 7. Number of regeneration seedlings in different gap areas. * represents $P < 0.05$.
Slika 7. Broj sadnica iz prirodne obnove u različitim površinama otvora. * predstavlja $P < 0,05$.

The desired position of Figure 6.

In addition, the number of grade I seedlings in forest gap of > 20 m² and number of grade IV seedlings in forest gap of < 10 m² were respectively significantly different from that in other levels of forest gap. We also found that the number of regeneration seedlings was the highest in the group of gap area > 20 m² in all four height Grade (Figure 7), which was consistent with our previous results that the larger gap area was favorable for cypress regeneration.

The desired position of Figure 7.

DISCUSSION
RASPRAVA

NR of cypress plantations is considered challenging, and evaluating the regeneration potential of cypress plantations is of great significance for scaling up the natural regenera-

Table 8. Number of cypress regeneration seedlings in different soil stone content
Tablica 8. Broj prirodnog pomlatka obične azijske tuje u tlu različite kamenitosti

Soil stone content *Kamenito tlo*	Grade I *Klasa I*	Grade II *Klasa II*	Grade III *Klasa III*	Grade IV *Klasa IV*	Renewal density individuals / hm² Gustoća obnavljanjapojedinačno / hm²
> 50%	146	128	109	103	48600
30% - 50%	31	17	12	7	6700
10% - 30%	10	6	2	2	2000
< 10%	11	7	5	6	2900

tion of cypress. In this study, plant density of regenerated seedlings in 20 sample plots was 0 individuals / hm^2, meaning no regeneration phenomenon. The reason for this phenomenon may be that these 20 plots are from the three sample survey areas where human activities were intensive. The frequent occurrence of concentrated human trampling incidents hindered the occurrence of seedlings. Morover, we revealed that NR through seed reproduction under appropriate environmental conditions could be achieved despite the rare NR of cypress plantation. The NR of cypress is closely related to the environment and stand factors. The suitable condition for NR of cypress is wet, high light intensity, soft soil, and low understory vegetation coverage.

We found that the number of Grade I, Grade II, Grade III, and Grade IV showed a decreasing trend, indicating that the number of young plant regeneration decreased with the increase of age; as well as implicating that the competition for regeneration plants from a young age to old age was fierce with high mortality. Competition becomes increasingly fierce when the supply of resources such as light and space cannot meet the needs of individual growth of the population. Thus, as young cypress individuals grow, the external environment requires that cypress seedlings be more resistant and adaptable to survive. As a result, the upper height level seedlings cannot stably enter the next stage, leading to a decline in the number of renewal seedlings.

The influence mechanism of herb coverage effect on cypress regeneration – *Utjecaj mehanizma pokrovnosti bilja na prirodnu obnovu obične azijske tuje*

This study found that there was a significant negative correlation between understory herb density and the number of cypress seedlings (Table 3; Figure 4), which was similar to the previous research results (Dyderski et al. 2018). The reason may be that cypress regeneration seedlings need nutrients and light during growth and development, which will produce fierce competition with herbs (Colmanetti et al. 2021). A competitive relationship between herbs and seedlings is driven by two reasons: They compete for photosynthetic nutrient space on the ground and nutrient and water resources underground; Herbaceous plants influence the behavior of herbivores and attract them to the area where the cypress is also located, increasing the risk destruction (Duclos et al. 2013). So, the regeneration of cypress seedlings will be suppressed due to the continuous increase of herb density (Montti et al. 2011). Therefore, for the investigated forest, the goal of promoting NR of cypress can be achieved by moderately thinning understory plants.

The influence mechanism of moss coverage effect on cypress regeneration – *Utjecaj mehanizma pokrovnosti mahovinom na prirodnu obnovu obične azijske tuje*

The number of cypress seedlings increased with increasing moss coverage (Table 3; Figure 4), suggesting that the density of cypress seedlings and moss coverage are beneficial to grow of each other. Mosses grow basically close to the ground and their high coverage rates contribute to improving soil moisture and reducing soil surface temperature. Studies reported that mossy mulch is associated with high mortality of small seed herbaceous plants (Fukasawa et al. 2019), which may be reduced the herbaceous plants competing for nutrients with cypress seedlings. Thus, a high moss coverage rate is conducive to cypress regeneration. On the one hand, different stand densities cause the heterogeneity of light and heat conditions in the forest, which impacted the growth and development of understory moss. On the other hand, the strong water and soil retention abilities of mosses provide a moist soil surface microclimate and inhibit herbaceous plant growth (Mallik and Kayes 2018). Last but not least, most of the water source needed by bryophytes is derived from atmosphere, thereby bryophytes do not compete with cypress regeneration seedlings for a large amount of water in the soil. Moreover, cypress is a sun-loving tree species but tolerates slightly shade rather than drought when young. To some extent, the growth habit of cypress in young stage resembles that of mosses. Therefore, for this study, the moss layer can not only provide a relatively humid growth environment for cypress seedlings and young trees but also act as a protective pad (Fukasawa,et al. 2018) . Conclusively, the higher moss coverage, the more suitable for NR of cypress.

The influence mechanism of soil stone content effect on cypress regeneration – *Utjecaj mehanizma kamenitosti tla na prirodnu obnovu obične azijske tuje*

In the present study, the number of cypress regeneration seedlings showed an upward trend with the increase of soil stone content. We speculated that increasing soil gravel content maybe elevate soil porosity thereby the roots of cypress seedlings are easier to take root. The soil with different stone content creates a completely different space for the root system of cypress seedlings from the pure soil, in which the factors have changed, such as water, fertility, gas, and temperature. In such an environment, cypress roots could actively regulate the accumulation of biomass by adjusting the physical distribution and changing the root metabolic rate, thus, the purpose of improving the growth level of cypress seedlings was achieved.

The influence mechanism of slope direction effect on cypress regeneration – *Utjecaj mehanizma ekspozicije na prirodnu obnovu obične azijske tuje*

Regeneration capacity of regenerated cypress seedlings was significantly affected by slope direction,this may be because that the intensity and hours of sunshine vary with slope directions, thus resulting in great differences in water, heat, physical and chemical properties of soil (Sewerniak 2016). According to our investigation results, the sunshine time was short and the light intensity was only 112.76 lum/ft^2 on shady slope, and the evaporation of soil water was small, with natural water content reaching up to 33.07%. Unlike shady slope, the sunshine time was long and the light intensity was 184.08 lum/ft^2 on sunny slope, of course, that the evaporation of the soil water was large and the natural water content of soil was low, with only 28.83%. Cypress seedlings are mostly distributed on the shady slope and semi shady slope due to the different illumination conditions. The illumination on shady slope is less than that on sunny slope, and the soil is relatively wet, which is conducive to cypress renewal (Yu et al. 2013). Therefore, in the investigated forest, slope direction has become the dominant factor of NR of cypress in semi-arid areas.

The influence mechanism of gap area effect on cypress regeneration – *Utjecaj mehanizma površine otvora na prirodnu obnovu obične azijske tuje*

In addition, the number of regeneration seedlings was also affected by gap area (Figure7), and the larger gap area was favorable for cypress regeneration. This phenomenon is not difficult to understand for sun-loving cypress seedlings, where the forest gap areas create more abundant light conditions. Next, when they grow up gradually, the influence of gap area becomes smaller due to entering the stable growth period. Therefore, the correlation between the number of cypress seedlings and gap area decreased with the height (grade). Generally, the factor of light was first changed by the formation of forest gap. the relatively large density of plantation results in insufficient light in the forest and a slow NR process. Therefore, with the increase of the gap area, the understory plants get more illumination time, more comprehensive light quality, and more physiologically effective radiation (Chen et al. 2018). Also, the distribution pattern of ambient temperature, humidity, and water resources around the understory plants (including cypress seedlings) also changed. Finally, the purpose of promoting cypress renewal was achieved. In short, in the investigated forest,the larger area of the forest gap, the better lighting conditions in the forest gap, more conducive to the regeneration of cypress seedlings.

Conclusion and prospective – *Zaključak i perspektiva*

In the investigated forest, compared with other tree species, the density and frequency of cypress regeneration seedlings are larger. The height distribution of cypress regeneration seedlings is mainly grade I seedlings, and there are few grade II, III, and IV regeneration seedlings. Thus, in future research, how to improve the survival rate of Grades II, III, and IV cypress regeneration seedlings could be studied.

In this study, the progress of cypress seedlings regeneration naturally was affected by stand factors and environmental factors. Especially, in stand factors, high density of herb was unfavorable to cypress regeneration while high moss coverage was contrary; in environmental factors, soil stone content, slope direction, and forest gap area were important environmental factors for promoting cypress regeneration. In the future management of cypress plantations, stand factors and environmental factors should be paid more attention to improve the regeneration of seedlings. For example, in the cypress seedling stage to properly loosen the soil, mix gravel particles or coarse materials into the soil to increase soil porosity, water permeability, and air permeability, timely watering and combing the grass to improve the light transmittance. In addition, the indexes of ground diameter and growth height of cypress regeneration seedlings are also related to the quality of regeneration status. Therefore, in the future research, the research on the ground diameter and growth index of cypress regeneration seedlings should be supplemented.

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Conflict of interest – *Sukob interesa*

The authors declare that they have no competing interests.

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SAŽETAK

Obična azijska tuja (*Platycladus orientalis* (L.) Franco) je jedno od važnih zimzelenih stabala za pošumljavanje u neplodnim planinama, za konsolidaciju tla i očuvanje vode, ali prirodna regeneracija obične azijske tuje je složena i spora. Razumijevanje mehanizma utjecaja na prirodnu regeneraciju obične azijske tuje bitno je za poticanje preživljavanja i regeneraciju. Cilj ovog istraživanja je objasniti odnos između šumskih sastojina, okolišnih čimbenika i regeneracije nasada obične azijske tuje. Ukupno 42 uzorka čempresa u Guilinu, Kina, odabrane su za procjenu utjecaja različitih čimbenika sastojine i okolišnih čimbenika na regeneraciju čempresa korištenjem statistike ankete i korelacijske analize Pearson i Spearmanrank. U ovoj studiji, obična azijska tuja ima najveću učestalost i gustoću regeneracije među svim sadnicama (18) u istraživanoj šumi, ali je visinska struktura sadnica obične azijske tuje raspoređena neravnomjerno, a radi se uglavnom o sadnicama I klase (visina < 30 cm). Bilje niske gustoće i malčiranje mahovine velike gustoće, imali su izravan pozitivan učinak na broj sadnica za regeneraciju obične azijske tuje. Veći sadržaj kamena u tlu i opustošenih površina mogu potaknuti regeneraciju obične azijske tuje, ali je to prikladnije za obične azijske tuje u fazi sadnice. Zaključno, pravodobno plijevljenje korova, pravilno rahljenje tla i poboljšanje propusnosti svjetla mogli bi potaknuti regeneraciju obične azijske tuje.

KLJUČNE RIJEČI: obična azijska tuja; čimbenik sastojina; čimbenik okoliša; prirodna regeneracija.

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PLANT DIVERSITY INDICES FOR TROJAN FIR STANDS IN ALADAĞ REGION OF BOLU

INDEKS BILJNE RAZNOLIKOSTI U SASTOJINI TROJANSKE JELE U ALADAĞ REGIJI BOLU

Emrah ERDOĞAN[1], Hayati ZENGIN[2]*, Mehmet ÖZCAN[3], Ahmet Salih DEĞERMENCI[4], Necmi AKSOY[5]

SUMMARY

640 samples in quadrates of 0.5 x 0.5 m obtained by systematic sampling method were evaluated. Samplings were made in two repetitions in GA (old), GB (young), GC (medium-aged), and GD (irregular) stand types, on north and south aspects. Field studies were carried out in 4 different periods (June, July, August, September) within the vegetation period. 122 plant taxa were determined at the level of species and intraspecific taxa. While 48 of the 122 plant taxa in fir stands were seen only in one of the stands, 41 plant taxa were detected in all stands. 5 taxa were seen only in GA stands, 7 in GB, 15 in GC and 13 only in GD stands, while 8 taxa could not be identified due to the insufficient vegetative and generative organs of the collected samples. The richest stand type in terms of taxa number was determined as the GC stand type with 84 plant taxa, but more individuals per ha were counted in the GA and GD stand types.

KEY WORDS: Trojan Fir, Plant diversity, Diversity indices, Stand, Aladağ, Turkey.

INTRODUCTION
UVOD

Forests are composed of stands, and stands cause microclimatic conditions by affecting the amount of light reaching the soil. This affects litter decomposition and soil nutritive conditions. These differences are also important in shaping the existence and distribution of plant species, which are described as understory flora or above-ground vegetation, and thus plant diversity. Stand structure is one of the more important factors affecting the similarity of species in a region (Svenning and Skov, 2002). Ister and Gökbulak (2009) stated that stand types have a significant effect on above-ground vegetation, where mixed stands create better growth conditions, while pure stands allow for more frequent and high-diversity flora formation. Pitkanen (1997) stated that there is a high correlation between the change in above-ground vegetation and site or stand age, while basal area, tree species mixture ratio and crown cover are other important factors in this change. Therefore, it is necessary to investigate the existence of such relationships in different sites in terms of different tree species and stand types.

Although forests are rich ecosystems in terms of biodiversity, there is not enough information about biodiversity values of different ecosystems to make comparisons or relative

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evaluations among them. Apart from conservation strategies, biodiversity information at the stand level, which is the smallest forest unit, is needed for planning in order to develop various strategies related to use and to set targets for planning and implementation.

Various floristic studies have been carried out in different regions of Turkey. These studies, which were carried out based on a specific area, not only focused on forest areas, but also tried to identify plants in other habitats in the area under consideration. Thus, although it is revealed which species are found in this area, information suitable for use in forest planning cannot be provided. These floristic studies were also carried out in the Bolu-Aladağ region of Turkey which was chosen as the study area in this research (Akman and Yurdakulol, 1981; Sazak, 1997; İkinci and Güner, 2007; Aksoy, 2010; Güneş Özkan and Aksoy, 2011; Tunçkol and Akkemik, 2013; Kanoğlu et al., 2016; Güneş Özkan et al., 2016; Koçer and Aksoy, 2016).

It will be useful to realize inventory studies on vegetative diversity on a basis that provides more information for forest planning, beyond providing a list of existing species in the area. More detailed studies on forest areas should be carried out, and the information on vegetative diversity should be expressed numerically depending on the stand types. Measuring diversity is of great importance in ecological research and conservation of biodiversity. Various indices have been developed to numerically express plant diversity depending on the presence and abundance of plants in an area (Lu et al., 2007). The Simpson index, Shannon index and total number of species are the most common indices used to describe diversity (Hill, 1973).

According to Nitzelius (1969) the geographically separated populations of *Abies nordmanniana* (Steven) Spach. in western and northern Turkey, described under the subspecies names and at various taxonomic levels, are found to be entirely clinal geographically. The typical subspecies occurs in western Caucasia (Abkhazia, Georgia) and in the mou-

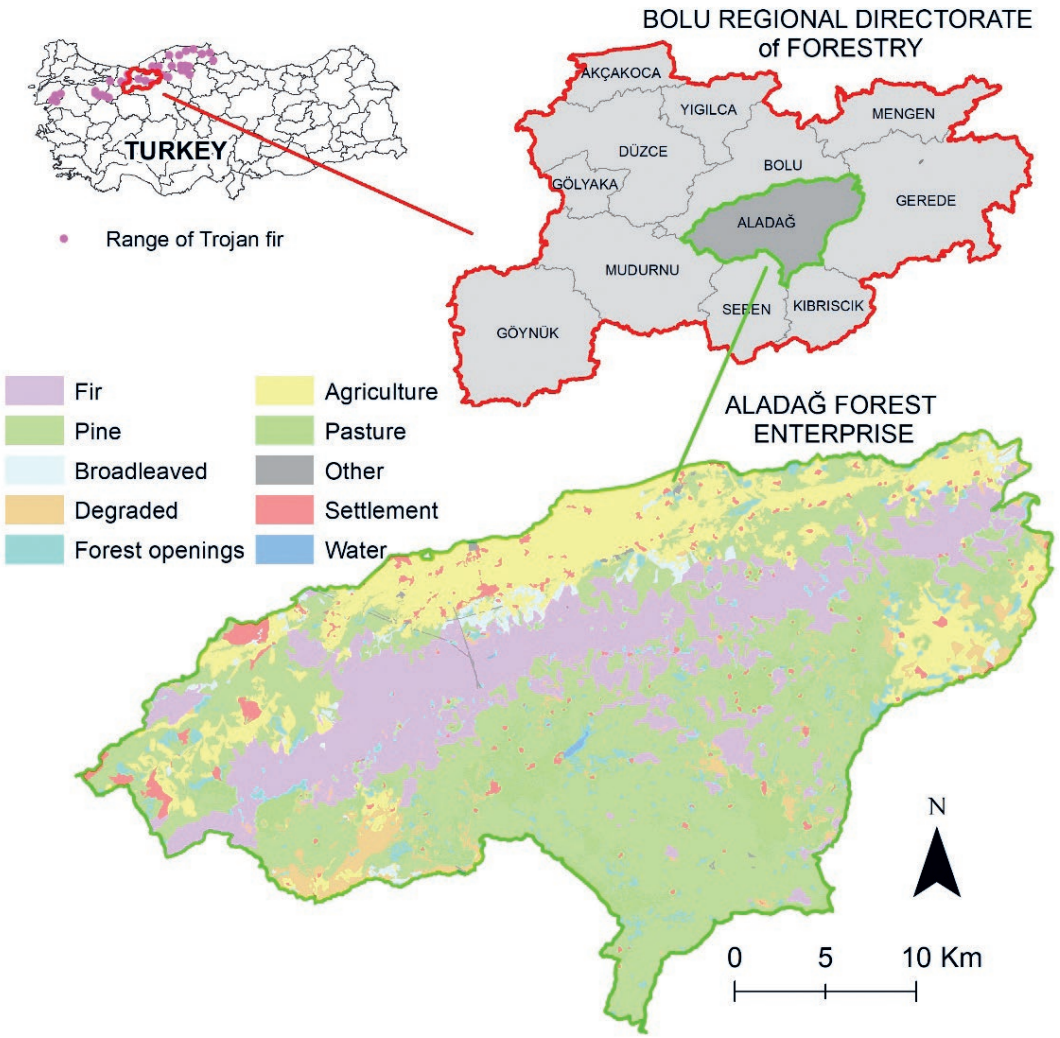

Figure 1. Location of the study area
Slika 1. Položaj područja istraživanja

ntains of north-eastern and north-western Turkey. Introgression with *Abies nordmanniana* (Steven) Spach. subsp. *equi-trojani* (Asch. & Sint. ex Boiss.) Coode & Cullen occurs in the western part of its range. *Abies nordmanniana* subsp. *equi-trojani* grows in pure stands as isolated relict populations on the north slopes of high mountains in western Turkey and on Uludağ in the western Black Sea Region of Turkey. It is a drought sensitive species (Yildiz et al., 2007) and prefers calcareous soils (Farjon, 1990).

In this study, beyond the standard flora studies, it is aimed to group the plant species and numbers in the Trojan fir (*Abies nordmanniana* (Steven) Spach. subsp. *equi-trojani* (Asch. & Sint. ex Boiss.) Coode & Cullen) forests in the Bolu-Aladağ region of Turkey depending on the stand types and to reveal the relationship of diversity indices with Trojan fir stands.

MATERIAL AND METHODS
MATERIJAL I METODE

General Characteristics of the Study Area – *Opće značajke područja istraživanja*

In order to reveal the vegetative diversity in the Trojan fir forests, the stands to be sampled were determined within the borders of the Aladağ Forest Enterprise, where the species is widely distributed. The study area is located between 31° 32' 35" - 31° 47' 15" E and 40° 34' 24" - 40° 40' 03" L (European Datum 1950) (Figure 1). The region is characterized by high mountainous terrain and generally consists of flat plateaus and wide plains between them (Dündar, 1989).

Although Aladağ is located in the Black Sea macro-climatic region, it shows some distinctions from this climate due to the presence of large mountain ranges in-between and because it is far away from the Black Sea coast. At the same time, a summer drought prevails in the region, which is characteristic for the area adjacent to the Central Anatolia steppe transition zone, although the rainfall is high. The annual average precipitation is 963 mm, and the annual average temperature is 6.2 °C (Dündar, 1989). The elevation of the sampling areas varies between 1500 m and 1700 m above sea level.

Determination of Stands for Sampling of Ground Flora – *Određivanje sastojina sa uzorkovanja prizemne flore*

The study was carried out in mixed-aged vertically layered fir stands. In the study, it was aimed to reveal the plant diversity in fir stands (GA, GB, GC, GD) on different aspects (north, south) in different periods (June, July, August, September) with two repetitions. 10 quadrates were taken in each stand in every sampling in different periods. The sam-

Table 1. Sampling pattern applied in the study
Tablica 1. Primijenjeni obrazac uzorkovanja

Stand Type (Tip Stalka) (4)	Aspect (Izgled) (2)	Repeat (Opet) (2)	Observation time (Vrijeme promatranja) (4)	Quadrate (četvrtast) (10)	Total Number Of Samples (Ukupni broj uzoraka) (640)
GA GB GC GD	North (Sjever) South (Jug)	2	June (Lipanj) July (Srpanj) August (Kolovoz) September (Rujan)	10	4*2*2*4*10=640

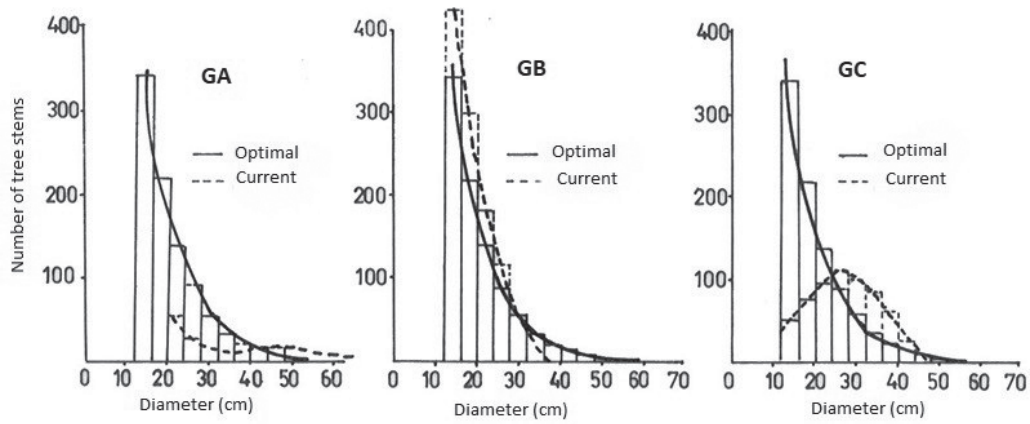

Figure 2. Current establishment types in fir forests
Slika 2. Trenutni tipovi objekata u jelovim šumama

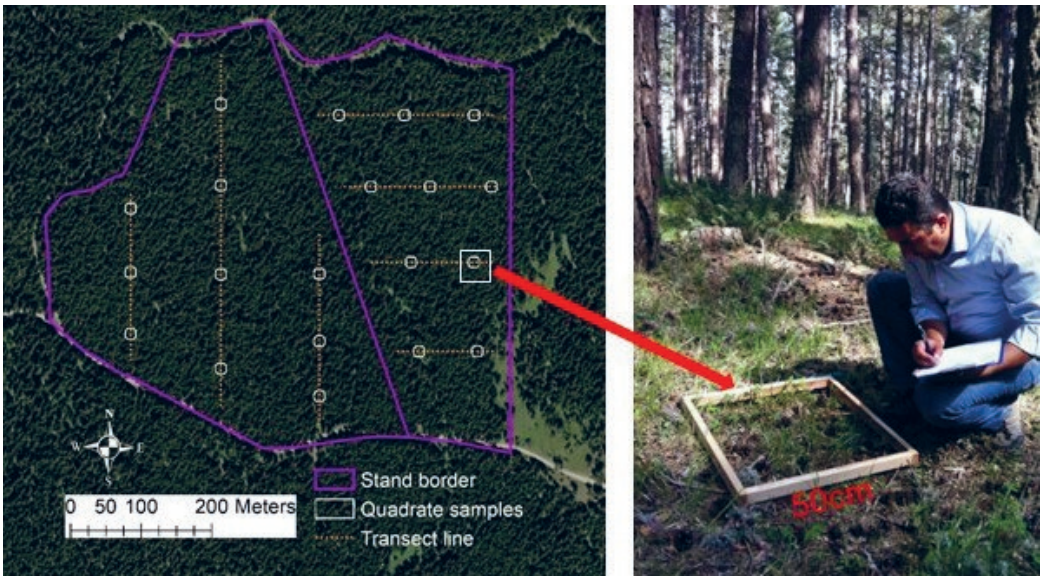

Figure 3. Quadrate sampling scheme for a sample stand
Slika 3. Kvadratna shema uzorkovanja za stalak za uzorke

pling design applied for this purpose and the information on the number of sample areas are given in Table 1. In the study, a total of 640 quadrate samples were taken from fir stands.

Trojan fir stands are divided into GA, GB, GC and GD groups (stand types) according to their structure. This distinction is made according to the distribution of the number of trees in the area to the diameter classes (Figure 2). GA stands represent a relatively old forest, and there is an excess in the thick diameter class of actual structure compared to the assumed optimal distribution of the tree numbers to the diameter classes. The GB type represents young stands, while GC stands represent middle-aged, vertically layered fir forests. The current number of trees in the thin layer in the GB stands and in the medium diameter class in the GC stands is higher than the optimal distribution. The GD type, on the other hand, shows different-aged vertically layered fir stands, which are not similar to the previous three types in terms of the distribution of stem numbers to the diameter class, and have an irregular structure. The stem volumes of the stands in the study area vary between 425-616 m^3/ha, and basal area is between 41.6-55.7 m^2/ha.

Sampling of the lower flora was carried out by applying the quadrate (frame) method along the strips (transects) (Figure 3). Before going into the field, the transect lines and the quadrate sampling locations on these lines were determined on the map. Transect lines were determined to be generally parallel to contour lines and to cover the whole area of the stands. Transect lines were constantly changed in the samplings made in different observation periods, and it was aimed to represent the whole area of the stands. Therefore, sampling was made in different places in the stands each time. 10 quadrate samples were taken every month in each stand. In this way, a total of 160 quadrate samples were taken each month for 16 stands. Quadrate sizes were 0.5 x 0.5m=0.25 m^2 and the number of different plants included in the frame were recorded in the survey report sheets. The names of the plants known in the field were recorded on the sheets, and for those that could not be identified, explanatory statements were written and plant samples were taken or photographed to identify them in the herbarium.

Calculation of Diversity Indices and Data Analysis – *Izračun indeksa raznolikosti i analiza podataka*

The values of the indices used to define plant diversity vary depending on the number of taxa in the area, the number of individuals belonging to the taxa, or the homogeneous distribution of the total number of individuals to the taxa. In this study, plant diversity is expressed by taxa diversity. Different indices are used to determine vegetative diversity in an area. When revealing diversity, two factors are generally taken into account, the richness and the abundance. The greater the richness and abundance, the greater the diversity. The evenness value is an approach based on whether the taxa in the area are represented by an equal number of individuals. In this study, the Shannon-Wiener, Simpson dominance, Simpson diversity and Pielou's evenness indices were used to define plant diversity.

The mathematical expressions used in calculating the indices are given below (Simpson, 1949; Shannon and Weaver 1963; Pielou, 1966).

Shannon-Wiener Diversity Index (SH):

$$SH = -\sum_{i=1}^{s} p_i \times \ln p_i$$

Simpson Dominance Index (D):

$$D = \sum_{i=1}^{s} p_i^2$$

Simpson Diversity Index (SI):

$$SI = 1 - D$$

Pielou's Evenness Index (PI):

$$PI = \sum_{i=1}^{s} \frac{SH}{\ln S}$$

In these indices, p_i: ratio of the number of plant species i to the total number of species, S: the total number of species.

The indices were analyzed at alpha and gamma levels. If a diversity calculation is made for each part of the community, the diversity in question is alpha diversity. Gamma diversity is a larger scale consideration made by bringing together a large number of communities. It is the total species diversity in a landscape. The same indices were used for alpha and gamma diversity. While values from 10 quadrates were brought together as one sample to find out the alpha diversity for a stand, gamma diversity was calculated from all the quadrates for a group of stand, aspect or observation time.

The PAST software (Hammer et al., 2001) was used to calculate the various index values used to determine the plant diversity. In order to determine the effect of stand type, aspect and observation time on plant diversity, multiple analysis of variance was performed and the averages were compared using the Tukey test.

RESULTS
REZULTATI

Observed Taxa – *Promatrani Taksoni*

The study area is within the borders of the Euro-Siberian phytogeographic region in terms of plant geography and is in the transition section to the xeric zone of Inner Anatolia. A total of 122 plant taxa were identified in the Trojan fir forests, of which 2 are family, 49 are genus, 59 are species, and 4 are subspecies and variety. Eight of these taxa could not be identified due to the insufficient vegetative and generative organs of the collected samples. While 48 plant taxa were seen in only one stand type in fir stands, 41 plant taxa were found in all stands. Except for unidentified taxa, 5 plant taxa were seen only in GA stands, 7 plant taxa in GB, 15 plant taxa in GC and 13 plant taxa only in GD stands (Table 2).

In terms of stand types, the highest number of taxa were found in GC (84) stands. This was followed by the GD (78), GA (70) and GB (63) stands, respectively. By periods, the highest number of taxa was seen in July with 82 units. The lowest number was observed in September with 54 units. When evaluated in terms of aspects, more taxa were detected on the southern aspects (100 taxa) than on the northern aspects (89 taxa) in fir stands. As a result of the study, the highest number of taxa was found in GC stands with 39 units in July and on the south aspect, while the fewest taxa

Table 2. Occurrence of taxa according to stand types in fir forests
Tablica 2. Pridolazak svojti prema tipovima sastojina u jelovim šumama

GA	GB	All stands (Svi stalci)	
Galium verum	*Cytisus hirsitus*	*Epilobium angustifolia*	*Veronica chamaedrys*
Mercurialis perennis	*Echium vulgare*	*Lapsana communis*	*Luzula campestris.*
Pitosphorum	*Juniperus oxicedrus*	*Pteridium aquilinum*	*Orthilia secunda*
Ranunculus brutius	*Lotus cornuculatus*	*Urtica dioica*	*Lathyrus laxiflorus*
Sanicula europea	*Polygala anatolica*	*Daphne pontica*	*Brachypodium sylvaticum*
	Silene italica	*Lapsana communis*	*Primula vulgaris*
	Verbascum blattaria	*Polystichum setiferum*	*Euphorbia amygdaloides*
		Cardamine bulbifera	*Veronica gentinoides*
GC	GD	*Lamium purpureum*	*Calamintha grandiflora*
Astragalus glycyphyllos	*Asperula involucrata*	*Epilobium montanum*	*Galium rotindifolium*
Centaurea triumfettii	*Brachypodium sylvaticum*	*Crepis foetida*	*Sanicula europea*
Cephalanthera longifolia	*Clinopodium vulgarea*	*Lathyrus laxiflorus*	*Trifolium spadiceum*
Dorycnium graecum	*Caucalis platycarpos*	*Mycelis muralis*	*Viola odorata*
Fagus orientalis	*Delphinium venilousum*	*Circium hypoleucum*	*Fragaria vesca*
Galium aperine	*Euphrasia pectinata*	*Doronicum orientale*	*Rubus hirsitus*
Salvia virgataMonotropa hypopitys	*Hypericum montbretii*	*Geranium pyrenacum*	*Galium rotundifolium*
Pilosella hoppeana	*Lapsana communis*	*Cyclamen coum*	*Veronica officinalis*
Potentilla recta	*Plantago lanceolta*	*Hieracium medianiforme*	*Abies nordmanniana*
Pyrola chlorantha	*Poa pratensis*	*Myosotis sylvatica*	*Oxalis acetosella*
Quercus cerris	*Sangiosorba minor*	*Helleborus orientalis*	*Phleum alpinum*
Sedum album	*Trifolium pratense*	*Erodium cicutarium*	
Silene vulgaris	*Vicia sativa*		
Sorbus torminalis			

Table 3. Number of taxa in fir stands according to aspect and observation period
Tablica 3. Broj svojti u jelovim sastojinama s obzirom na izloženost i razdoblju promatranja

	June (Lipanj)	July (Srpanj)	August (Kolovoz)	September (Rujan)	Total (Ukupno)
GA	42	41	35	34	70
South (Jug)	32	31	26	27	56
North (Sjeverno)	32	25	31	24	51
GB	36	32	30	35	63
South (Jug)	24	19	22	22	43
North (Sjeverno)	23	29	22	29	50
GC	41	50	47	37	84
South (Jug)	31	39	34	29	64
North (Sjeverno)	20	31	25	23	54
GD	47	41	37	36	78
South (Jug)	31	30	34	22	61
North (Sjeverno)	33	27	24	28	53
Total (Ukupno)	77	82	61	54	122

Table 4. Plant individual numbers (individuals/m²) in fir stands according to the aspect and observation period
Tablica 4. Broj jedinki biljaka (jedinki/m² u sastojinama jele s obzirom na izloženost i razdoblje promatranja

	June (Lipanj)	July (Srpanj)	August (Kolovoz)	September (Rujan)	Average (Prosjek)
GA	124	144	180	113	140
South (Jug)	130	157	189	132	152
North (Sjeverno)	119	131	171	94	129
GB	63	127	128	109	107
South (Jug)	79	119	103	88	97
North (Sjeverno)	48	134	152	129	116
GC	83	127	136	106	113
South (Jug)	102	132	141	124	125
North (Sjeverno)	64	122	131	89	101
GD	134	189	181	122	156
South (Jug)	153	191	215	102	165
North (Sjeverno)	116	187	148	141	148
Average (Prosjek)	101	147	156	113	129

were observed in the GB stands in July and on the south aspect (Table 3).

In terms of stands, the highest average number of individuals per unit area (m²) was found in GD (156) stands. This was followed by the GA (140), GC (113) and GB (107) stands, respectively (Table 4). The highest number of individuals with 215 units/m² was observed in GD stands in August and on the south aspect, while the lowest number of individuals was observed in June in the GA stands and on the north aspect. In terms of periods, the highest average number of individuals was seen in August with 156 units. The lowest number was observed in June with 101 units. When evaluated in terms of aspects, 135 individuals/m² were found on the south-facing slopes, while 123 units/m² were found on the north-facing slopes. (Table 4).

The number of plant taxa differs according to the observation period. While some plant taxa such as *Astragalus glycyphyllos* (June), *Centaurea triumfettii* (July), *Filipendula vulgaris* (August), and *Pilosella hoppeana* (September) were observed only in a certain period, some taxa such as *Calamintha grandiflora*, *Cirsium hypoleucum*, *Digitalis ferruginea*, and *Helleborus orientalis* were observed during all pe-

Table 5. Occurrence of taxa in fir forests according to observation time
Tablica 5. Pridolazak svojti u jelovim šumama prema vremenu promatranja

June (Lipanj)	July (Srpanj)	August (Kolovoz)	Seen Every Period (Uvijek videno)	
Astragalus glycyphyllos	*Campanula glomerata ssp. hispida*	*Cephalanthera longifolia*	*Abies nordmanniana* **ssp**	*Lathyrus laxiflorus*
Brachypodium sylvaticum	*Centaurea triumfettii*	*Euphrasia pectinata*	*Brachypodium sylvaticum*	*Lathyrus laxiflorus*
Cardamine bulbifera	*Cytisus hirsutus*	*Filipendula vulgaris*	*Calamintha grandiflora*	*Melica uniflora*
Clinopodium vulgare	*Dauscus laciniata*	*Rubia sanctus*	*Circium hypoleucum*	*Orthilia secunda*
Dorycnium greaecum.	*Delphinium venulosum*	*Sangiosorba minor*	*Crepis foetida*	*Oxalis acetosella*
Echium vulgare	*Dorycnium graecum*	*Vicia sativa*	*Daphne pontica*	*polystichum setiferum*
Euphorbia amygdaloides	*Galium aperine*		*Digitalis ferruginea*	*Primula vulgaris.*
Fagus orientalis	*Hypericum hyssopifolium*		*Epilobium montanum*	*Pteridium aquilinum*
Lamium garganicum	*Sucutlelleria oreintalis*		*Erodium cicutaurium*	*Rubus sanctus*
Lapsana communis	*Monotropa hypopitys*	**September (Rujan)**	*Euphorbia*	*Salvia forskahlei*
Moneses uniflora	*Plantago major*	*Asperula involucrata*	*Fragaria vesca*	*Sanicula europea*
Ranunculus brutius	*Plantago lanceolata*	*Galium verum*	*Galium rotundifolium*	*Trifolium hybridum*
Sedum acre	*Poa protensis*	*Lotus cornuculatus*	*Galium odoratum*	*Urtica dioica*
Sorbus torminalis	*Polygala anatolica*	*Pilosella hoppeana*	*Geranium asphodeloides*	*Veronica officinalis*
Verbascum blattaria	*Potentilla rupetris*	*Pyrola chlorantha*	*Helleborus orientalis*	*Veronica gentinoides*
	Quercus cerris	*Trifolium pratense*	*Hieracium medianiforme*	*Viola odarata*
	Sanicula europea			*Viola suavis*
	Silene italica			
	Silene vulgaris			

Table 6. Occurrence of taxa in fir forests according to aspects
Tablica 6. Pridolazak svojti u jelovim šumama s obzirom na izloženost

North (Sjeverno)	South (Jug)	Both North and South (I Sjever i Jug)	
Asperula involucrata	*Brachypodium sylvaticum*	*Abies nordmanniana*	*Lamium purpureum*
Astragalus glycyphyllos	*Centaurea triumfettii*	*Barbarea vulgaris.*	*Lapsana communis*
Cephalanthera longifolia	*Cytisus hirsitus*	*Brachypodium sylvaticum*	*Lathyrus laxiflorus*
Clinopodium vulgare	*Dactylis glomerata*	*Bromus ramosus*	*Luzula campestris*
Delphinium venulosum	*Caucalis platycarpos*	*Calamintha grandiflora*	*Melica uniflora*
Echium vulgare	*Dorycnium graecum*	*Campanula rapunculoides*	*Moneses uniflora*
Mercurialis perennis	*Euphorbia amygdaloides*	*Cardamine bulbifera*	*Mycelis muralis*
Monotropa hypopitys	*Euphrasia pectinata*	*Carex muricata*	*Myosotis sylvatica*
Poa pratensis	*Fagus orientalis*	*Circium hypoleucum*	*Orthilia secunda*
Polygala supina	*Galium aperine*	*Circium arvense*	*Oxalis acetosella*
Potentilla recta	*Galium verum*	*Clinopodium vulgare*	*Plantago major*
Pyrola chlorantha	*Hypericum montbretii*	*Crepis foetida*	*Polygonatum orientale*
Ranunculus brutius	*Juniperus oxycedrus*	*Cyclamen coum*	*Polystichum setiferum*
Silene vulgaris	*Lapsana communis*	*Daphne pontica*	*Primula acaulis*
Trifolium medium	*Lotus cornuculatus*	*Digitalis ferruginea*	*Primula vulgaris*
Verbascum blattaria	*Pilosella hoppeana*	*Doronicum orientale*	*Prunella vulagris*
	Plantago major	*Epilobium lanceolatum*	*Pteridium aqulia*
	Platanhera bifolia	*Epilobium montanum*	*Pyrola minor*
	Poa trivalis	*Epilobium montanum*	*Asperula arvenisi*
	Prunella vulgaris	*Erodium cicutarium*	*Rubus sanctus*
	Quercus petraea	*Euphorbia stricta*	*Rumex acetosella*
	Sangiosorba minör	*Filipendula vulgaris*	*Salvia forskahlei*
	Sanicula europea	*Fragaria vesca*	*Salvia verticillata*
	Sedum album	*Galium rotundifolium*	*Sambucus ebulus*
	Silene italica	*Galium verum*	*Sanicula europea*
	Sorbus torminalis	*Geranium purpureum*	*Trifolium medium*
	Trifolium pratense	*Geranium robertianum*	*Urtica dioca*
	Vicia cracca	*Helleborus orientalis*	*Veronica chamaedrys*
		Hieracium medianiforme	*Veronica officinalis*
		Lamium garganicum	*Veronica gentinioides*
			Viola odarata
			Viola suavis

riods during the study. Occurrences of taxa in different periods are given in Table 5.

While 67 taxa were seen on both northern and southern aspects in fir stands, the number of taxa seen only in the north was 22, and the number of taxa seen only in the south was 33. Taxa such as *Barbarea sp.*, *Brachypodium sylvaticum*, *Bromus sp.*, and *Calamintha grandiflora* were observed in both north and south views. However, taxa such as *Asperula involucrata*, *Astragalus glycyphyllos*, and *Cephalanthera longifolia* were seen only in the north, while taxa such as *Brachypodium sylvaticum*, *Centaurea triumfettii*, *Cytisus hirsutus*, and *Dactylis glomerata* were observed only in the south (Table 6). 8 taxa could not be identified due to the insufficient vegetative and generative organs of the collected samples, and were not included in the tables.

Findings on Plant Diversity Indices – *Nalazi o indeksima biljne raznolikosti*

In this study, diversity indices were calculated at two levels, alpha and gamma, and the findings were evaluated under separate sections. Within the scope of the study, diversity indices calculated at alpha level were used in the statistical analyses carried out to determine the differences in diversity indices determined according to stand type, aspect and observation time.

Findings of Alpha Diversity – *Rezultati alpha raznolikosti*

When the fir stands were compared with each other in terms of the Simpson diversity index, it was determined that the stand type, aspect and observation time did not have a statistically significant effect on taxa diversity. However, it was found that the stand type-aspect interaction had a statistically significant effect on diversity ($P<0.05$). According to these results, in terms of the Simpson diversity index, the lowest diversity was measured in the GB stands with 0.84 on south aspects, and the highest diversity was measured as 0.89 on south aspects of GC stands and north aspects of GB stands (Table 7).

When the fir stands were evaluated in terms of the Shannon diversity index, it was determined that the stand type and aspect did not have a statistically significant effect on taxa

Table 7. Aspect-stand type interaction in fir stands according to Simpson's index

Tablica 7. Interakcija izloženost – tip sastojine u jelovim sastojinama prema Simpsonovom indeksu

Stand Type (Tip Stalka)	South (Jug)	North (Sjever)
GA	$0,88^{ab} \pm 0,01$	$0,86^{ab} \pm 0,02$
GB	$0,84^{a} \pm 0,03$	$0,89^{ab} \pm 0,03$
GC	$0,89^{b} \pm 0,04$	$0,86^{ab} \pm 0,03$
GD	$0,87^{ab} \pm 0,04$	$0,85^{ab} \pm 0,02$

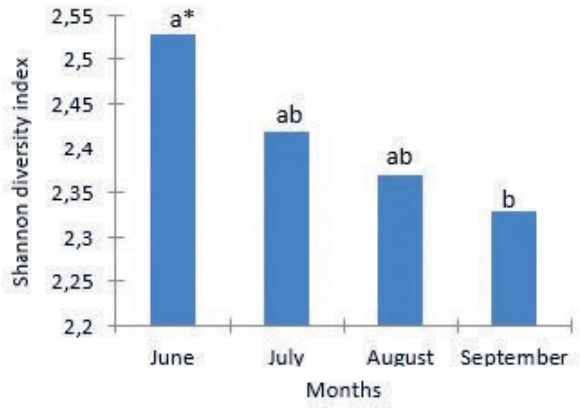

Figure 4. Periodic variation of Shannon diversity index in fir stands
*Similar letters on the columns show there is no significant differences between the means

Slika 4. Sezonska varijabilnost Shannonovog indeksa raznolikosti u sastojinama jele
* Slična slova na stupcima pokazuju da nema značajnih razlika između srednjih vrijednosti

diversity (P>0.05), but a significant change in plant diversity in observation periods was registered (P<0.05). The highest taxa diversity was measured in June (2.53), while the lowest diversity was measured in September (2.33) (Figure 4).

It was also determined that the stand type-aspect interaction had a significant effect on diversity (P<0.05). According to the Shannon diversity index, the highest diversity was measured in the GC stands with 2.65 on the south aspect and the lowest diversity was measured in the GB stands on the south aspect with 2.15 (Table 8).

Table 8. Aspect-stand type interaction in fir stands according to Shannon index

Tablica 8. Interakcija aspekt-sastojina u jelovim sastojinama prema Shanononovom indeksu

Stand Type (Tip stalka)	South (Jug)	North (Sjeverne)
GA	$2,51^{bc} \pm 0,12$	$2,41^{abc} \pm 0,14$
GB	$2,15^{a} \pm 0,20$	$2,51^{bc} \pm 0,22$
GC	$2,65^{c} \pm 0,28$	$2,28^{ab} \pm 0,15$
GD	$2,41^{abc} \pm 0,32$	$2,36^{abc} \pm 0,14$

When the fir stands were examined in terms of evenness values, it was determined that the stand type, aspect and observation period did not have a significant effect on the homogeneous distribution of the plants in the area (P>0.05). In addition to this, the interactions did not affect the species distribution (P>0.05).

Findings of Gamma Diversity – *Rezultati gamma raznolikosti*

The indices in this section, which represent larger populations (e.g, fir stands on south aspects), represent gamma diversity. Therefore, large regions were evaluated as the sampling area, and the species and numbers belonging to this area were evaluated together. While calculating the diversity indices of the GA stands, the taxa and numbers of 4 (observation time) *2 (aspect)*10 (quadrate)*2 (repetition) =160 quadrate samples were evaluated together. Also, the other stands were evaluated similarly.

In the study, a total of 122 taxa were determined in fir stands. Gamma diversity in fir stands is 0.96 according to the Simpson index and 3.64 according to the Shannon index. In terms of gamma diversity, the lowest Simpson index was measured as 0.93 in the GB stands and the highest as 0.96 in the GC stands. While the average Shannon diversity index value was 3.41, the lowest value was determined in GB stands with 3.21 and the highest was determined in GC stands with 3.57 (Table 9).

While the highest number of taxa was observed in July with 82, the lowest number was seen in September with 54. In terms of observation period, the highest diversity according to the Shannon index for fir stands was in June (3.51), and this decreased gradually towards August and started to rise again in September (3.31). The Simpson diversity index shows a similar trend to the Shannon index (Table 10).

The number of taxa and individuals were higher on the south aspects. Shannon diversity index values were also higher in the south than in the north. The Shannon value was 3.59 on the south aspect and 3.58 on the north aspect, while the Simpson diversity index values were determined as 0.96 for both aspects (Table 11).

When the stand type-observation period interaction was examined, the highest diversity according to the Shannon index was observed in July and September in GC stands with a value of 3.22. The lowest value of 2.62 was observed in GB stands in August. According to the Simpson diversity index, the highest value of 0.95 was observed in GA stands in July and in GC stands in September. The lowest value of 0.89 was observed in GD stands in August. Evenness values ranged between 0.40 and 0.68 (Table 12).

According to the Shannon index, the highest diversity was observed in GC stands with a value of 3.41 on the south aspect. The lowest value, with 2.73, was observed in the GB stands again on the south aspect. Only for this stand type,

Table 9. Variation of diversity indices according to stand types
Tablica 9. Varijabilnost različitih indeksa s obzirom na tipove sastojina

Stand Type (Tip stalka)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
GA	160	70	0,05	0,95	3,45	0,45
GB	160	63	0,07	0,93	3,21	0,39
GC	160	84	0,04	0,96	3,57	0,42
GD	160	78	0,05	0,95	3,40	0,38

Table 10. Variation of diversity indices according to observation time
Tablica 10. Varijacija indeksa raznolikosti prema vremenu promatranja

Observation time (Vrijeme promatranja)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
June (Lipanj)	160	77	0,04	0,96	3,51	0,43
July (Srpanj)	160	82	0,05	0,95	3,43	0,38
August (Kolovoz)	160	61	0,06	0,94	3,21	0,40
September (Rujan)	160	54	0,05	0,95	3,31	0,51

Table 11. Variation of diversity indices according to aspects
Tablica 11. Varijacija indeksa raznolikosti prema aspektima

Aspect (Izgled)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
South	320	100	0,04	0,96	3,59	0,36
North	320	89	0,04	0,96	3,58	0,40

Table 12. Diversity indices by stand type and observation time
Tablica 12. Indeksi raznolikosti prema vrsti sastojine i vremenu promatranja

Stand Type (Tip staništa)	Observation Time (Vrijeme promatranja)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
GA	June (Lipanj)	42	0,07	0,93	3,00	0,48
	July (Srpanj)	41	0,05	0,95	3,19	0,59
	August (Kolovoz)	35	0,10	0,90	2,71	0,43
	September (Rujan)	34	0,07	0,93	2,98	0,58
GB	June (Lipanj)	36	0,07	0,93	2,96	0,54
	July (Srpanj)	32	0,10	0,90	2,70	0,47
	August (Kolovoz)	30	0,10	0,90	2,62	0,46
	September (Rujan)	35	0,07	0,93	2,98	0,56
GC	June (Lipanj)	41	0,07	0,93	3,08	0,53
	July (Srpanj)	50	0,06	0,94	3,22	0,50
	August (Kolovoz)	47	0,06	0,94	3,15	0,50
	September (Rujan)	37	0,05	0,95	3,22	0,68
GD	June (Lipanj)	47	0,07	0,93	3,12	0,48
	July (Srpanj)	41	0,07	0,93	2,99	0,49
	August (Kolovoz)	37	0,11	0,89	2,69	0,40
	September (Rujan)	36	0,09	0,91	2,85	0,48

the Shannon value in the south was lower than in the north. In other fir stands, the Shannon diversity index for the south aspect was either equal to or higher than the north. According to the Simpson diversity index, the highest value was 0.95 and this value was seen on the southern aspects of fir stands, except GB. The Simpson diversity index for

Table 13. Diversity indices by stand type and aspect
Tablica 13. Indeksi raznolikosti s obzirom na tip sastojine i izloženost

Stand Type (Tip stalka)	Aspects (Izgled)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
GA	South	56	0,05	0,95	3,34	0,50
	North	51	0,05	0,95	3,34	0,55
GB	South	43	0,10	0,90	2,73	0,36
	North	50	0,05	0,95	3,34	0,56
GC	South	64	0,05	0,95	3,41	0,47
	North	54	0,06	0,94	3,13	0,42
GD	South	61	0,05	0,95	3,28	0,43
	North	53	0,05	0,95	3,19	0,46

Table 14. Diversity indices in fir stands by aspect and observation period
Tablica 14. Indeksi raznolikosti u sastojinama jele s obzirom na izloženost i razdoblje promatranja

Aspects (Izgled)	Observation Time (Vrijeme promatranja)	Number of Quadrates (Kvadratni broj)	Number of Taxa (Broj svojti)	Dominance (Dominacija)	Simpson	Shannon	Evenness (Ujednačenost)
South (Jug)	June (Lipanj)	80	60	0,05	0,95	3,36	0,48
	July (Srpanj)	80	61	0,05	0,95	3,31	0,45
	August (Kolovoz)	80	55	0,07	0,93	3,11	0,41
	September (Rujan)	80	44	0,06	0,94	3,19	0,55
North (Sjeverne)	June (Lipanj)	80	53	0,06	0,94	3,29	0,51
	July (Srpanj)	80	59	0,05	0,95	3,33	0,47
	August (Kolovoz)	80	47	0,06	0,94	3,10	0,47
	September (Rujan)	80	45	0,05	0,95	3,25	0,57

GB on the south aspect was 0.90, which was the lowest level for fir stands. Also, the evenness value (0.36) of GB stands on the south aspect was the lowest. Interestingly, the north aspects of these stands had the highest evenness value with 0.56 (Table 13).

Among the fir stands, the highest diversity by aspect and observation period according to the Shannon index was seen in June on the southern slopes with a value of 3.36. The lowest value was 3.10 in August in the north. While the lowest evenness value was observed in August with 0.41 on the south aspect, the highest value in the north was observed in September with 0.57 (Table 14).

DISCUSSION
RASPRAVA

With this study, taxa were determined by sampling in 640 quadrate samples in GA, GB, GC and GD stands of fir forests on north and south aspects from June to September. Shannon and Simpson diversity index values were calculated at alpha and gamma diversity levels in these stands.

122 taxa were determined at the level of variety, subspecies, species, genus and family. However, in a situation of whole stand area survey, it could be expected that the number of taxa would be higher for this region. Beus and Vojniković (2005) identified 56 plant species in mixed fir and beech species in Bosnia and Herzegovina. Although our study was realized in pure stands of Trojan fir, their value is less than half of our results. There can be many factors effecting floristic composition. Also, there are mixed stands of fir with pine around our study area, but we did not focus on them. By carrying out the diversity analysis in different forest stands with step-by-step researches, it can be possible to compare similar areas in terms of diversity and make a classification. Redowan (2015) made a classification of diversity indices for Majella National Park (Italy) by arranging the index values and classifying them from low to high to compare different forest areas in the national park. A similar global system can be developed by carrying out the diversity index analyses for different regions.

Among 122 taxa, some, like *Calamintha grandiflora*, *Fragaria vesca*, *Helleborus orientalis*, and *Rubus sanctus* were registered in all stand types (GA, GB, GB, SE) from June to September. However, considering the aspect conditions, it was determined that only *Fragaria vesca* was seen in quadrates in all cases. *Fragaria vesca* is an important taxon for wildlife, as well as for cultivation for its fruits. It is an important product that should be evaluated as a non-wood forest product in terms of planning. It can also be used as an income-generating product for the local people.

Graae and Heskjaer (1997) did not observe the effect of stand structure on species diversity in their study to determine the differences between managed and non-managed forests. However, they stated that there is less species rich-

ness in older stands. Also, Behera and Misra (2006) did not find a significant difference among the stands in terms of the Shannon diversity index in their study on the analysis of herbaceous vegetation in four different stands consisting of broad-leaved species. On the other hand, Pitkanen (1997) reported that species richness is higher in young stands and in the fertile areas, and also, albeit at a lesser level, the basal area, crown cover and species mixing ratio in trees are also influential on this. Contrary to this, Zhu et al. (2009) indicated that species diversity was greatest in the mid-successional stage, which appears similar to our results. This can be interpreted as a peaked (n-shaped) diversity - age (or diameter) class relationship, while Gosper et al. (2013) found a U-shaped relationship between diversity and time since fire. In this study, based on the gamma diversity level, relatively young stands (GB) have the poorest diversity in terms of the Simpson and Shannon indices. They peak in GC stands and then decrease in GA stands, which represent the older (thicker) areas.

In the statistical analyses based on the diversity indices calculated at the alpha diversity level, there were no significant differences in terms of the Simpson diversity index in fir stands according to stand type, aspect and observation period. However, stand type-aspect interaction had a significant effect on diversity. Since the fir stands have a vertically layered structure, it is assumed that the more stable and similar microclimatic conditions in the stand are responsible for this. On the other hand, while there were no significant differences in terms of stand type and aspect among the diversity values found according to the Shannon index, it was seen that observation period was effective and that the diversity decreased periodically from June to September. It is thought that with the beginning of the vegetation period, a large number of plants began to appear, but that later on, due to both the climatic conditions and the life span of the plants, they disappeared from the area. The Shannon diversity indices in fir stands (except GB) on the southern aspects had higher values than the northern aspects. Graae and Heskjaer (1997) stated that soil moisture is influential on vegetation. Although no soil moisture measurements were carried out in this study, it is thought that favorable site conditions for diversified species under the vertical and thick crown layer of fir stands can be formed on south aspects with more sunlight. Since the study area is adjacent to the steppe transition zone and the partial drought seen in the summer months affects the distribution of plants in terms of species and quantity, the decrease in diversity from June to September can be explained by the fact that some species disappear due to summer drought or their short vegetation period.

Periodic differences in vegetative diversity indices or plant richness may also have resulted from the sampling method used. As a matter of fact, the quadrate (frame) samples taken from the stands were not at the same place in every period of observation, and conscious systematic shifts were made in order to better represent the stands. For this reason, since the plants are not homogeneously distributed in the forest stand area, the plants observed in one place in the stand might not be seen in other areas around. So, some plants may not have coincided with the quadrates and may have not been evaluated as to whether they exist in the area. Although this type of sampling is advantageous in terms of revealing the plant richness of the stands, it may lead to the fact that sparse plants in the area cannot be sampled every time, and that therefore, they are considered as dried out and lost from the environment.

CONCLUSION
ZAKLJUČAK

Only the developmental stages of stand types change under normal conditions while forests are being managed. Therefore, knowing the plant diversity in terms of stand types will help to predict the future vegetative diversity depending on the change of stand types over time. With the present study, the vegetative diversity values of the stands for fir were revealed. From this, diversity can be calculated for different forest areas and for the entire forest. In this way, vegetative diversity can be determined numerically and steps can be taken towards its integration into forest planning and management.

Since fully stocked stands (having a closure of more than 70%) will be formed under successful forest management conditions, this study has been limited to this type of stand. It is necessary to present the vegetative diversity numerically for different closure situations, even for different site and elevation situations and in different tree species. In this way, comparisons can be made in terms of tree species and stand types by using vegetative diversity indices such as site class, which expresses the wood yield strength of a habitat.

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SAŽETAK

Procijenjeno je 640 uzoraka 0,5x0,5 m dobivenih metodom sustavnog uzorkovanja. Uzorkovanje je obavljeno u dva ponavljanja u GA (staroj), GB (mladoj), GC (srednjedobnoj), GD (nepravilnoj) sastojini, na sjevernim i južnim izloženostima. Terenska istraživanja provedena su tijekom 4 različita razdoblja (lipanj, srpanj, kolovoz, rujan) unutar vegetacijskog razdoblja. Određene su 122 biljne svojte na razini vrsta i infraspecifičnih svojti. U samo jednoj sastojini jele zabilježeno je 48 biljnih svojti, 41 svojta zabilježena je u svim sastojinama. 5 svojti biljaka viđeno je samo u GA sastojinama, 7 u GB, 15 u GC i 13 samo u GD sastojinama. Najbogatiji tip sastojine po broju svojti utvrđen je kao GC tip sastojine sa 84 biljne svojte, ali je više jedinki po ha izbrojano u GA i GD sastojinama.

KLJUČNE RIJEČI: Trojanska jela, Raznolikost biljaka, Indeksi raznolikosti, Sastojina, Aladağ, Turska.

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OPTIMIZATION OF PRIMARY FOREST ACCESSIBILITY IN HIGH FORESTS WITH NATURAL REGENERATION

OPTIMIZIRANJE OTVORENOSTI VISOKIH ŠUMA S PRIRODNOM OBNOVOM

Vladimir PETKOVIĆ[1]*, Dane MARČETA[1], Igor POTOČNIK[2]

SUMMARY

Optimization of primary forest accessibility is observed from the point of intensity of forest management and terrain relief conditions of the forest area. Optimization of primary forest accessibility is the first phase of the planning of primary forest traffic infrastructure. The second phase is designing of new primary forest traffic infrastructure. The high forests with natural regeneration (high forests) in the public forests are selected for optimization of accessibility because they are the most valuable forest category from the point of quantity and quality of timber. Planning of primary forest traffic infrastructure implies analysis of actual primary forest accessibility of high forests, determination of optimal density of primary forest traffic infrastructure, defining of suitability of high forests area for construction of primary forest traffic infrastructure and upgrading of actual primary forest traffic infrastructure with new routes of primary forest traffic infrastructure. Optimization of primary forest accessibility in hilly and mountainous high forests was done in two Management Units, Prosara and Bobija-Ribnik. Optimal density of primary forest traffic infrastructure ranges from 24 to 26 m/ha. Results showed that high forests have potential for sustainable forest management.

KEY WORDS: primary forest traffic infrastructure, GIS, multicriteria evaluation

1. INTRODUCTION AND RESEARCH PROBLEM
1. UVOD I PROBLEMATIKA ISTRAŽIVANJA

Sustainability and durability of timber production, as well as other forest products, and the use of forest area can be determined as an optimal forest management. From the aspect of forest harvesting, optimization is utilization of the timber with the minimal total costs of transportation (Dobre 1995). Transport of timber is a very significant and the most expensive part of the forest harvesting. According to Sokolović and Bajrić (2013a) the transport costs make around 80 % of total harvesting costs. Determination of the optimal forest road location in forest landscape is an important part of harvesting planning, especially from the point of economic and environmental aspect (Akay et al. 2013). The planning of primary forest accessibility is a spatial issue of forest management optimization (Kaya et al. 2016).

According to Sokolović and Bajrić (2013a) the average primary forest accessibility in BiH is 10.15 m/ha, while accessibility in primary forest traffic infrastructure in the high forests with natural regeneration (high forests) is 11 m/ha. Accessibility of the public forests by public and forest roads

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in entity of Republic of Srpska (RS) is around 9.4 m/ha. Accessibility of the high forests with primary forest traffic infrastructure is 11.6 m/ha. Average density of the primary forest traffic infrastructure is 9.28 m/ha in public forests (Sokolović and Bajrić 2013a, Anon 2017, Anon 2019).

Intensive forest management requires density of forest roads over 30 m/ha (Dobre 1995). The ground skidding is the most common timber extraction method in BIH (Marčeta et al. 2014). Density of forest roads depends on extraction type and it should be 25 m/ha for ground skidding in Europe (Dykstra and Heinrich 1996). Recent research in RS showed that the accessibility in some cases could be significantly higher than in official documents and can rise up to 14 m/ha (Potočnik et al. 2013), considering both aspects, production, and terrain characteristics in hilly area.

Pentek et al. (2014) determined the primary forest accessibility from 5 m/ha in karst region to 15 m/ha in mountainous region, and around 11 m/ha in hilly region. Actual density of forest, fire and public roads in Slovenia is around 25 m/ha (Krč and Beguš 2013). Trajanov et al. (2015) determined that primary forest accessibility is 13.43 m/ha in Northern Macedonia. Total primary forest accessibility is around 27 m/ha by forest roads in public forests of Republic of Serbia (Anon 2018). The average forest accessibility is 45 m/ha by forest roads in Austria (Ghaffarian et al. 2009, Findeis 2016).

The actual accessibility of the forest, to be more precise, public forests in RS is lower than in some neighbouring countries and it does not provide an opportunity for sustainable utilisation, regeneration and protection. The consequence of that is the fact that timber harvesting is carried out on a reduced area (Anon 2011). Accessibility of the forests in RS should be improved and it is necessary to approach to the planning of new forest roads. This action consists of planning of primary forest accessibility and designing of new forest roads.

The aim of planning of forest roads is achieving targeted density of forest roads from the point of intensity of forest management, terrain and stand conditions to reduce the average extraction distance. That can be achieved by planning of new routes of the forest roads in suitable areas which are not enough accessible.

General steps in improving of forest accessibility are:

1. analysis of actual primary forest accessibility,
2. defining of targeted forest density of primary forest traffic infrastructure based on forest management intensity and terrain conditions,
3. analysis of achieved primary forest accessibility.

In this study, these tasks will be implemented into two different relief areas and types of high forests.

2. MATERIAL AND METHODS
2. MATERIJAL I METODE

In high forests in RS (61 % of total area of public forests), there are about 5,440.50 km of forest roads and according to it, high forests belong to the most accessible forest category (Anon 2017). High forests with natural regeneration are usually managed by the group-selection management system. The application of this management system forms various age-structured and mixed stands. In this investigation for optimization of accessibility in hilly and mountainous high forests, based on their timber production, terrain and stand characteristics and intensity of forest management, two Management Units (MU), Prosara and Bobija-

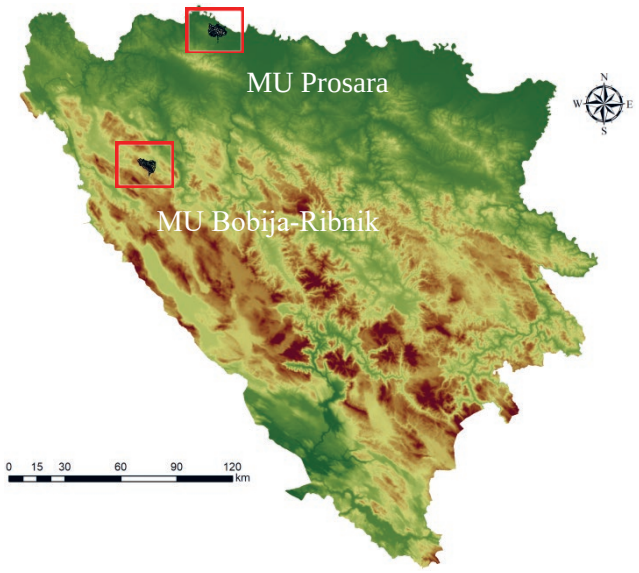

Figure 1. Location of MU Prosara and Bobija-Ribnik in BIH
Slika 1. Lokacija GJ Prosara i Bobija-Ribnik u BIH

Table 1 The characteristics of high forests in selected MUs (Anon 2013a, 2013b)
Tablica 1 Svojstva prirodnih šuma u odabranim GJ (Anon 2013a, 2013b)

MU	Area / *Površina* ha	Growing stock / *Drvna zaliha* m³/ha	Annual increment / *Godišnji prirast* m³/ha	Allowable cutting volume / *Sječivi etat* m³/ha			Primary accessibility / *Primarna otvorenost* m/ha
				Roundwood/ *Oblo drvo*	Fuelwood/ *Ogrijev*	Residue/ *Ostatak*	
Prosara	3,470	267.2	6.7	23.11	13.04	12.64	7.3
Bobija-Ribnik	4,180	413.1	11.27	47.5	13.98	23.95	15.66

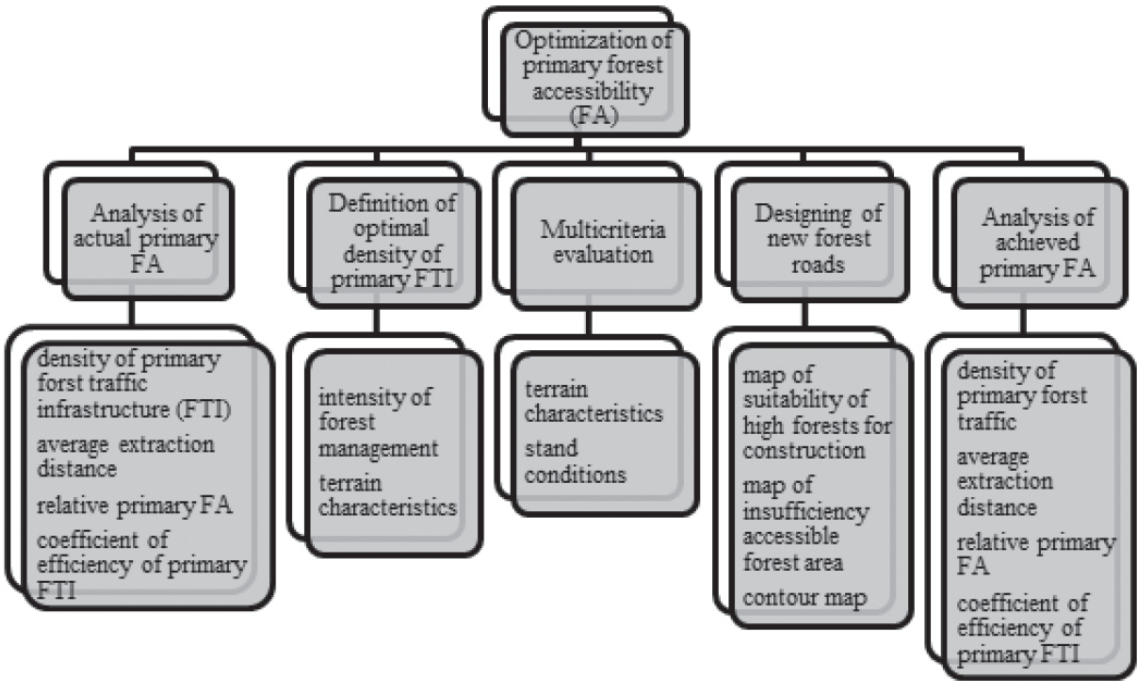

Figure 2. Flow of optimization of primary forest accessibility
Slika 2. Tok optimiziranja primarne otvorenosti šuma

Ribnik are selected (Figure 1). The high forests of the selected areas consist of mixed forests of beech and sessile oak, beech and fir with spruce and beech forests. Soil types range from deep and acidic to carbonate and dolomite soils as follows calcomelanosol, calcocambisol, luvisol and rendzina. As it can be seen, the high forests are diverse in the structure of tree species, plant communities, terrain and stand characteristics (Table 1).

The relative ratios of species are 59 % of beech, 29 % of sessile oak and 12 % of the other species of broadleaves in high forests with natural regeneration of MU Prosara. The relative ratio of broadleaves is 54 % and coniferous 46 % in high forests with natural regeneration of MU Bobija-Ribnik, and the ratio of fir is 33 %, spurce 13 % and beech 43 % respectively (Anon, 2013a, 2013b).

Research method is presented in the Figure 2.

2.1. Analysis of primary forest accessibility - Analiza primarne otvorenosti

The actual primary forest accessibility of forest area is usually expressed by density of primary forest traffic infrastructure, average extraction distance, relative primary forest accessibility and coefficient of efficiency of primary forest traffic infrastructure (Pentek et al. 2005, Sokolović and Bajrić 2013a).

Forest roads influence on the primary forest accessibility depending on its length, spatial distribution and extraction possibility. Poršinsky et al. (2017) defined four basic and five spatial criteria for determination of density of roads in forest. The basic criteria define the properties of roads which make a forest accessible. Spatial criteria determine an influence of roads on primary forest accessibility depending on their position in the forest area. The primary forest traffic infrastructure density is determined based on current length of forest roads, and in this investigation are recorded by GARMIN 62 ST hand held GPS device.

The second indicator of primary forest accessibility is extraction distance and it is observed like geometrical. The geometrical skidding distance is perpendicular distance from harvesting area to the forest road and it is shorter than the real one for value of skidding factor. The geometrical extraction distance is determined by method of Euclidean distance in ArcGIS 10. (Đuka et al. 2017). Harvesting technology that is most commonly used in BIH implies felling and processing of the trees at the stump by chainsaw and extraction of the assortments to the landing site. The most common harvesting method is the assortment method. Timber extraction is carried out by skidders mostly, so it can be spoken of a skidding distance (Marčeta et al. 2014).

Backmund (1966) introduced relative forest accessibility as an indicator of total forest accessibility, and it represents ratio between accessible forest area by primary forest traffic infrastructure and total forest area. That area is defined by width of buffer zone around of primary forest traffic infrastructure and it is equal to double targeted geometrical skidding distance (Pentek et al. 2005, Hayati et al. 2012, Sokolović and Bajrić 2013a). It is calculated by Equation 1:

$$O_R = \frac{P_O}{P_U} \times 100 \quad \text{... (1)}$$

where:

O_R – relative forest accessibility (%),
P_O – the accessible forest area (ha),
P_U – the total forest area (ha).

The forest is insufficiently accessible if relative primary forest accessibility is up to 55 %, it is poorly accessible if it is between 56 and 65 %, hardly well accessible if it is between 66 and 75 %, very well accessible if relative accessibility is between 76 and 85 % and excellent accessible if it is over 85 % (Pentek et al. 2005).

Efficiency coefficient of forest roads network represents the relation between ineffective surfaces, that are multiple accessible, and the total single accessible areas for double average targeted geometrical skidding distance (Pentek et al. 2005, Potočnik et al. 2013, Sokolović and Bajrić 2013a). The multiple accessible areas is obtained by using ArcGIS Geoprocessing tool Intersect as the extricate areas from single accessible areas of buffer zone around primary forest traffic infrastructure. It is calculated by Equation 2:

$$k_U = \left(1 - \frac{P_N}{P_O}\right) \times 100 \quad (2)$$

where:

k_U – efficiency coefficient of the forest road network (%),
P_N – surface of the inefficiency of bordered areas (multiple accessible areas) (ha),
P_O – accessible area for the chosen double aimed geometrical skidding distance (single accessible areas) (ha).

This coefficient represents grade of the impact of the forest roads on the accessibility. This efficiency coefficient should be as higher as possible, because lower coefficient means that roads are multiple overlapping and crossing.

2.2. Optimization of primary forest accessibility – *Optimiziranje primarne otvorenosti*

Optimization means determination of the optimal or targeted density of primary forest traffic infrastructure. The targeted density of primary forest traffic infrastructure will be determined on the basis of recommended density of primary forest traffic infrastructure for normal and intensive forest management and for certain relief regions. Targeted density of primary forest traffic infrastructure is 30 m/ha from the point of intensity forest management (Dobre 1995).

By local regulation provided targeted density of primary forest traffic infrastructure, based on the relief regions and local regulative should be:

- Lowland area – 12 km/1000 ha,
- Hilly area – 18 km/1000 ha,
- Mountainous area – 22.5 km/1000 ha and
- Karst area – 12 km/1000 ha (Anon 2015).

In general, the targeted density of primary forest traffic infrastructure is only a guide for planning of primary forest accessibility for MUs and FMA (Forest Management Administration) and it will be achieved depending on many factors. Multi-criteria evaluation of terrain and stand conditions of forest area is a convenient way for determining of relative strength of influence for each factor.

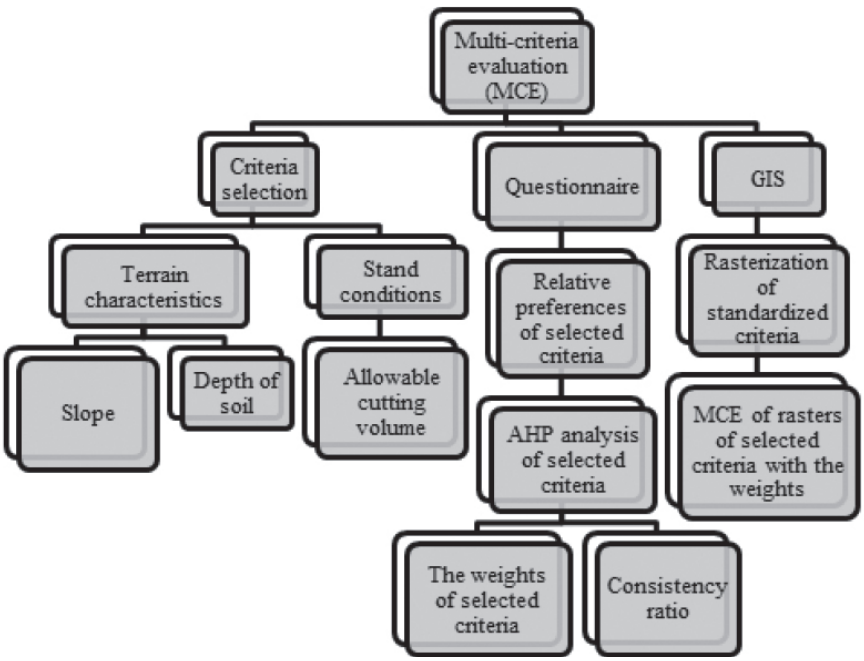

Figure 3. Process of multicriteria evaluation
Slika 3. Proces višekriterijske evaluacije

2.3. Multicriteria evaluation (MCE) – Multikriterijska evaluacija (MCE)

It is necessary to upgrade the actual with new routes of primary forest traffic infrastructure in order to achieve the targeted accessibility and reduce actually skidding distance. At this point, the question is in which area roads should be built. That issue could be solved by defining the suitability area for primary forest traffic infrastructure. The area suitable for construction of primary forest traffic infrastructure will be obtained by spatial analysis in ArcGIS 10 by using the tool Weighted Sum.

This analysis is based on multicriteria evaluation (MCE) of terrain and stand characteristics of forest area (Figure 3). The most common subcriteria used for defining suitability of area for primary forest traffic infrastructure construction in other researches are: terrain slope, growing stock and soil depth (Figure 3) (Abdi et al. 2009, Sokolović et al. 2009, Mohammadi et al. 2010, Caliskan 2013, Lepoglavec 2014, Petković and Potočnik 2018, Petković 2019, Petković et al. 2019). The suitability of area for construction was obtained by addition of standardized raster of influential factors (by Equation 3), which are weighed for each factor. Thematic maps of influential factors with resolution of 5x5 m were obtained by spatial analysis of DTM or data collected from field research and forest management documentation in ArcGIS 10. The weight of each factor means its influence on the suitability of area for forest road construction. These weights were obtained by AHP method. In order to determine weights of influential factors in defining of suitability area for forest road construction in this research a Questionnaire was prepared for assessing the impact of criteria. It was sent to relevant forest-engineering scholars for assessing. The influence of the slope, soil and timber growing stock on determination of area suitability for forest road construction is determined on the basis of opinion of 14 respondent. The average scores which were obtained by questionnaire for each criterion were standardized by Equation 3 and compared to pairwise matrix according to AHP methodology. This method was developed by Tomas Saaty (1980, 2008) and it was created as an auxiliary tool of multicriteria decision-making.

$$X_i = \frac{(R_i - R_{\min})}{(R_{\max} - R_{\min})} \times X_{\max} \qquad (3)$$

where:

x_i – standardized value,
R_i – basic value,
R_{min} – lower value of basic scale,
R_{max} – upper value of basic scale,
X_{max} – upper average value of standardized scale.

Based on the level of suitability and spatial distribution of insufficient accessible forest areas into MU, the new routes of primary forest traffic infrastructure are planned.

2.4. Designing of new routes of primary forest traffic infrastructure – *Projektiranje novih trasa primarnih šumskih prometnica*

The new routes of primary forest traffic infrastructure have to fulfil minimal technical requirements regulated by the Manual for designing of truck roads (Anon 2002). At the general level, they are designed by setting up the zero line on contour map by method of equal length of segments of zero line between contour lines, under constant longitudinal slope. In order to set up of zero line, it is necessary to form contours based on DTM resolution 5x5 m with equidistance of 5 m using ArcGIS 10 tool Extraction Contour. Then, contour lines should be connected with segments of zero line with equal lengths with constant longitudinal grade. The most important constructive element of zero line is maximal longitudinal grade of forest road surface, and it is 8 % (Anon 2002, Petković and Potočnik 2018, Petković et al. 2019). According to previous, minimal length of a segment of zero line is 62.5 based on contour equidistance and road maximal longitudinal grade. Setting up the zero lines is done in insufficient accessible and areas suitable for construction of forest roads in high forests. It is necessary to check a quality of upgraded forest roads network from the point of indicators of primary forest accessibility based on average targeted density of primary forest traffic infrastructure.

3. RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Two MUs have been chosen from PFC ŠUME RS, which are in two different FMAs, with different terrain and stand characteristics, which are managed by group-selection forest management system. The results of spatial analysis of DTM show that MU Prosara belongs to lowland-hilly area (91 – 362 m a.s.l.) (Figure 4) and MU Bobija-Ribnik belongs

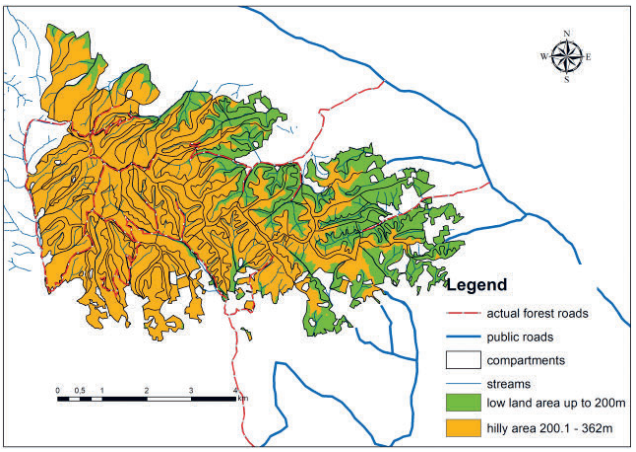

Figure 4. Relief regions in Prosara
Slika 4. Reljefna područja u Prosari

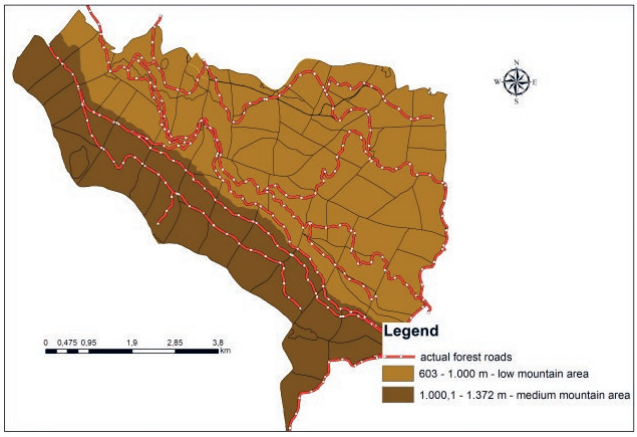

Figure 5. Relief regions in Bobija-Ribnik
Slika 5. Reljefna područja u Bobiji-Ribnik

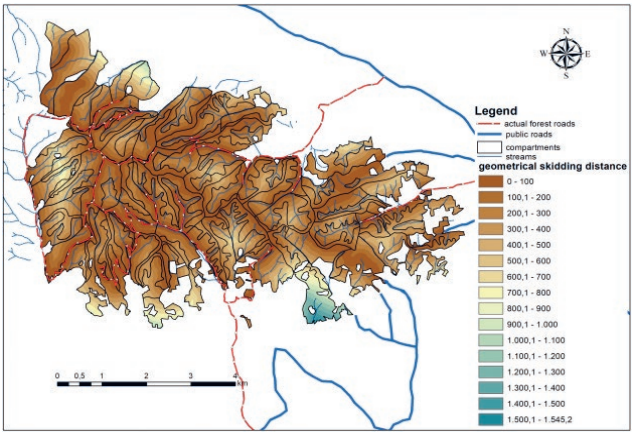

Figure 6. Actual geometrical skidding distance in Prosara
Slika 6. Trenutna geometrijska daljina privlačenja u Prosari

to low and average mountain relief area (603 – 1372 m a.s.l.) (Bertović 1999) (Figure 5).

The results show that accessibility of high forests is higher than one in Forest Management Plans (FMP) (Anon 2013a, 2013b) (Table 1) because of higher vector length of forest roads (Table 2).

These values allow only extensive forest management (Dobre 1995). As it was shown in Table 2, the actual forest road density is higher in mountainous than in lowland-hilly areas. The reason for this is the fact that public and forest railways were intensively built in some period in the past because of intensively utilization of timber from fir and spruce forests in mountainous area. Considering relief areas, Anon (1998) recommends density of primary forest traffic infrastructure from 7 to 10 m/ha in hilly areas and up to 35 m/ha on steep terrain. Enache et al. (2016) determined that density of forest roads is 18.5 m/ha in mountainous region of Europe. According to that, it can be concluded that investigated MUs have the recommended forest accessibilities. That means that overall primary forest accessibility is achieved considering relief areas to which both selected MUs belong.

The average geometrical Euclidean skidding distances (Figure 6 and 7) (Table 2) are lower for 23 m in MU Prosara and 38 m in MU Bobija-Ribnik than the geometrical skidding distances obtained by method of distance of gravity centre of compartments from route of the forest road, which are 510 m and 281 m respectively (Petković and Potočnik 2018, Petković et al. 2019).

The average values of targeted densities in selected MUs (Table 3), allow normal forest management and they are suitable for ground skidding extraction according to Dykstra and Heinrich (1996). The average targeted densities of primary forest traffic infrastructure, which are based on total cost of transport and allowable cut volume of roundwood, are 16 m/ha for MU Prosara and 26.5 m/ha for MU Bobija-Ribnik (Petković and Potočnik, 2018, Petković , 2019, Petković et al., 2019). According to Master plan of for-

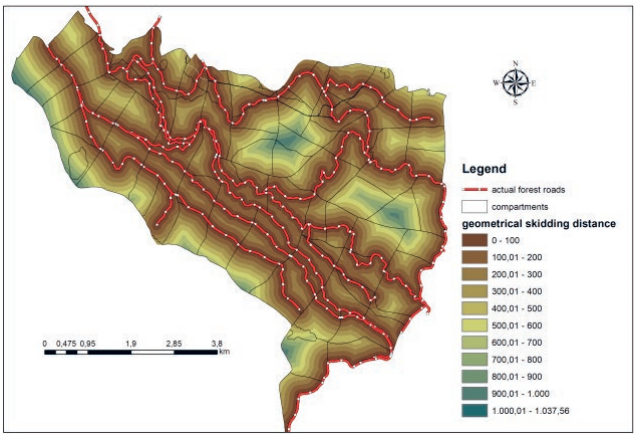

Figure 7. Actual geometrical skidding distance in Bobija-Ribnik
Slika 7. Trenutna geometrijska daljina privlačenja u Bobiji-Ribnik

Table 2. Indicators of actual primary forest accessibility
Tablica 2. Pokazatelji trenutne primarne otvorenosti šuma

MU/*GJ*	Density of primary forest traffic infrastructure / *Gustoća primarne šumske prometne infrastrukture* (m/ha)	Average geometrical skidding distance / *Srednja geometrijska daljina privlačenja* (m)	Relative primary accessibility / *Relativna primarna otvorenost* (%)	Coefficient of efficiency of primary forest traffic infrastructure / *Koeficijent efikasnosti primarne šumske prometne infrastrukture* (%)
Prosara	9	487	49	73
Bobija-Ribnik	17	243	91	10

Table 3. Average targeted densities of primary forest traffic inftastructure
Tablica 3. Prosječna ciljna gustoća primarnih šumskih prometnica

Density / *Gustoća* (m/ha)	Normal and intensive forest management / *Normalno i intenzivno gospodarenje šumama*	Relief region / *Reljefni region*	Average / *Prosjek*
MU Prosara	30	18	24
MU Bobija-Ribnik	30	22.5	26

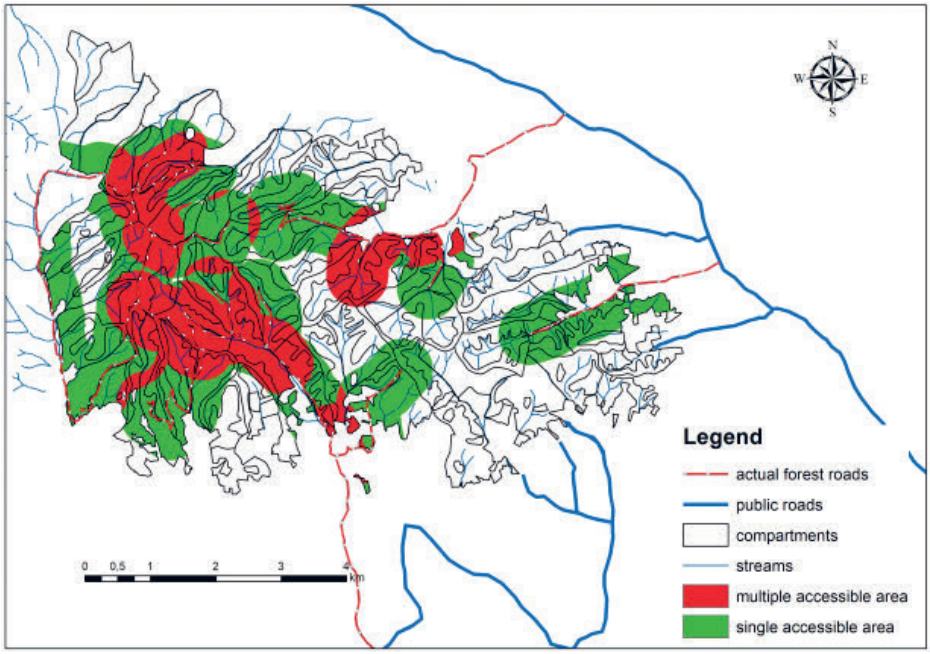

Figure 8. Efficiency of actual forest roads network in Prosara
Slika 8. Kvaliteta trenutne mreže primarne šumske prometne infrastrukture u Prosari

est roads in RS average targeted densities for these two MUs are 17.47 m/ha and 19.85 m/ha (Anon 2019). Thus, the actual forest road density is lower than the targeted one and the targeted density of primary forest traffic infrastructure is higher in mountainous than in the hilly areas (Table 3).

The real skidding distance for obtained average targeted densities in of these MUs ranges from 250 to 308 m. The average targeted geometrical skidding distance is 189 m in MU Prosara and 283 m in MU Bobija-Ribnik. They are calculated by Rebula's (1981) equation and they are lower than values of actual geometrical skidding distances.

The single accessible high forests area is 1,666.073 ha and multiple accessible area is 442.26 ha in Prosara (Figure 8). The single accessible high forests area is 3,817.94 ha, and multiple is 3,427.15 ha in MU Bobija-Ribnik for double-targeted geometrical skidding distance (Figure 9). The grade of relative primary forest accessibility ranges from poorly to excellent. The coefficient of efficiency should be as high as possible because it is the indicator of quality of designing of forest roads (Table 2).

Multicriteria evaluation of the terrain slope, growing stock and soil depth of the chosen areas determined suitability of investigated forests area for construction of primary for-

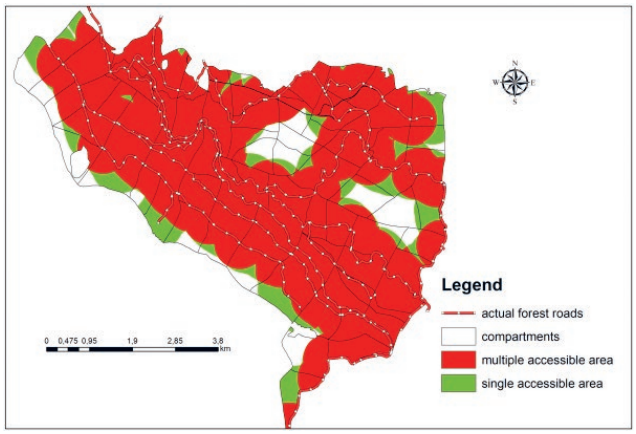

Figure 9. Efficiency of actual forest roads network in MU Bobija-Ribnik
Slika 9. Kvaliteta trenutne mreže primarne šumske prometne infrastrukture u Bobiji-Ribnik

est traffic infrastructure. Slope of terrain ranges from 0 to 122 %, depth of soil ranges up to 340 cm, and growing stock ranges from 150 to 455 m^3/ha. The influence of the selected subcriteria was obtained by AHP method. Based on the average original values for each subcriterion from questionnaire (slope 2.57, depth of soil 1.71 growing stock 2.5), actually their standardized values (slope 0.786, depth

Table 4. Pairwise matrix sub-criteria
Tablica 4. Matricauspoređivanja podkriterija

	slope	depth of soil	growing stock
slope	1	2.2	1.047619048
depth of soil	0.4545455	1	0.476190476
growing stock	0.9545455	2.1	1
sum	2.4090909	5.3	2.523809524

of soil 0.357 growing stock 0.75), and the results of the pairwise comparison (Table 4) weights of the subcriteria are slope 0.42, depth of soil 0.19 and growing stock 0.40 (Table 5). This is input for determination of suitability of high forests area for construction of primary forest traffic infrastructure (Petković, 2019, Petković et al. 2019). The suitable forest areas for the primary forest traffic infrastructure cover 99 % surface in the both MUs.

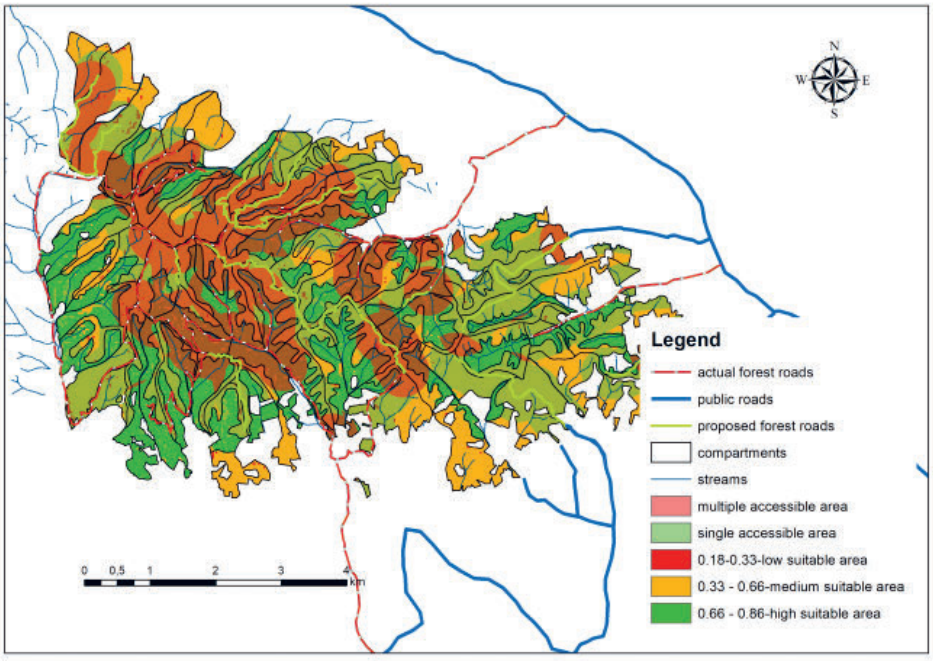

Figure 10. Indicators of achieved primary forest accessibility in Prosara
Slika 10. Pokazatelji dostignute primarne otvorenosti šuma u Prosari

Table 5. Matrix normalized vectors
Tablica 5. Matrica normaliziranih vektora

	slope	depth of soil	growing stock	weight	sum	consistency of matrix
slope	0.415	0.415	0.415	0.415	1.245	3
depth of soil	0.189	0.189	0.189	0.189	0.566	3
growing stock	0.396	0.396	0.396	0.396	1.189	3
sum	1	1	1	1	λ_{max}	3
					CI	0
					RI	0.58
					CR	0

λ_{max} – maximum value of pairwise matrix, CI –consistensy index, RI-random index, CR – consistency ratio

Table 6. Indicators of achieved primary forest accessibility
Tablica 6. Pokazatelji dostignute primarne otvorenosti šuma

	Density of primary forest traffic infrastructure / *Gustoća primarne šumske prometne infrastrukture* (m/ha)	Average geometrical skidding distance / *Srednja geometrijska daljina privlačenja* (m)	Relative primary forest accessibility / *Relativna primarna otvorenost* (%)	Coefficient of efficiency of primary forest traffic infrastructure / *Koeficijent efikasnosti primarne šumske prometne infrastrukture* (%)
MU Prosara	13.5	247	79	56
MU Bobija-Ribnik	21	158	97	9.1

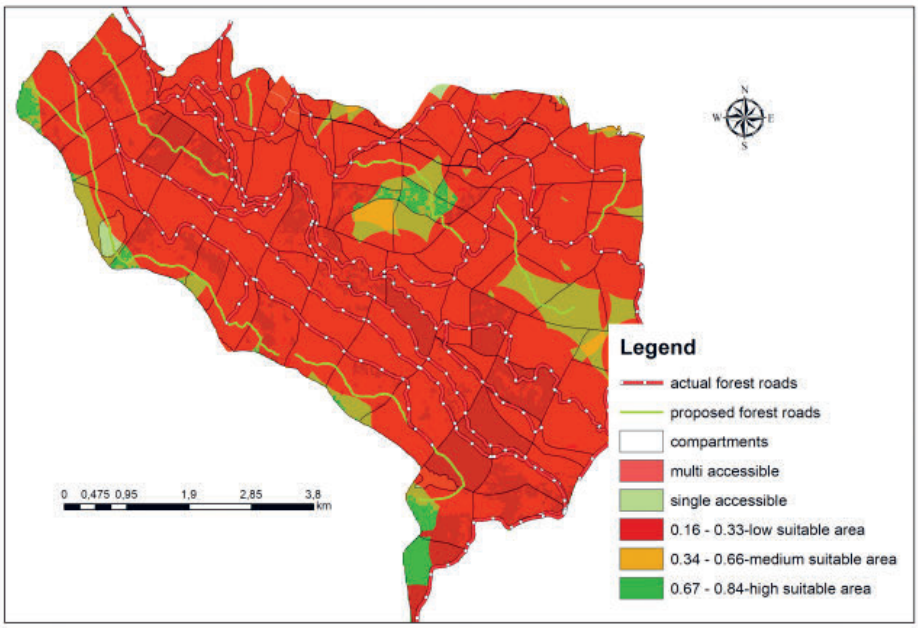

Figure 11. Indicators of achieved primary forest accessibility in Bobija-Ribnik
Slika 11. Pokazatelji dostignute primarne otvorenosti šuma u Bobiji-Ribnik

In this way starts the phase of forest roads designing at the general level where its set up zero lines on suitability maps. Zero lines are placed in areas suitable for the construction and insufficiently accessible at the same time, considering watercourse protection and prescribed horizontal and vertical alignments of the forest roads (Figures 10 and 11).

Thus, in MU Prosara is set up 21 km of zero lines for new primary forest traffic infrastructure and around 22 km in MU Bobija-Ribnik. Density of primary forest traffic infrastructure is enlarged for 6.24 m/ha and 5.15 m/ha (Table 6).

The achieved geometrical skidding distance obtained by Euclidean's algorithm (Table 5) are lower than the actual ones. The multiple accessible high forests area is 1,202.82 ha and single accessible is 2,719.215 ha for double average targeted geometrical skidding distance in MU MU Prosara. In MU Bobija-Ribnik single accessible area is 4,247.513 ha and the multiple accessible high forests area for double average targeted geometrical skidding distance is 3,860.64 ha (Figure 10 and 11). The grades of relative primary forest accessibility for upgraded forest roads network range from very well in MU Prosara to excellent in MU Bobija-Ribnik for double average targeted geometrical skidding distance and they are increased in comparison with actual primary forest traffic infrastructure. The coefficients of efficiency of upgraded primary forest traffic infrastructure are slightly decreased in comparison with coefficients of efficiency for the actual one (Table 6).

Summarizing the results of research, it can be said:

- Actual primary forest accessibility is insufficient for normal and intensive forest management. This statement is based on analysis of actual primary forest traffic infrastructure from the point of its density.
- Analysing of achieved primary forest accessibility on the basis of upgraded primary forest traffic infrastructure from the point of its density, it can be confirmed that achieved primary forest accessibility is lower than targeted, but the quality of achieved primary forest accessibility is raised.

4. CONCLUSIONS
4. ZAKLJUČCI

Today a comprehensive process of planning of primary forest accessibility is present which includes all of the aspects of usage of forests and forest area. Apart from timber production and usage of the other forest resources, terrain and stand characteristics, it includes protection of forest environment, usage of forest area in health, sports and cultural purpose. That is a large number of numerical and descriptive data whose collection, surveying and analysis require usage of the achievements in the field of IT technology. The devices and software's such as GIS, SPSS, RoadEng programme packages and GPS are necessary for modern planning of forest roads and their management.

Using of GIS software's (ArcGIS, GlobalMapper or QGIS) requires quality data for spatial and statistical analysis. Quality of these data can be provided by Light Detection Airborne Ranging (LiDAR) system. On the basis of LiDAR scanning of ground Digital Elevation Model (DEM) could be made.

Here, the focus was on the primary forest traffic infrastructure designing in the public forests. The reason for this is that the private forests are small and fragmented, scattered on wide area. Often, for private forests, the property relations are not resolved. The mobilization of the private forest-owners can be increased then when a better logistics, infrastructure and organizational conditions are provided (Pezdevšek Malovrh et al. 2017).

The results of the research suggest the necessity of making of the studies of the primary forest accessibility for MUs based on comprehensive analysis of terrain characteristics, stand conditions, traffic infrastructure and the other criteria. The analysis requires making of GIS analysis of MUs based on data collected from FMPs, surveyed in the field or obtained from DTM. The results of should be embedded into FMPs in which is necessary to do analysis, comparison and monitoring of the planned and realized activities in optimization of forest accessibility.

This increase of primary forest accessibility will be burdened with the higher costs of timber harvesting and transport due to introduction of new technology and the planning of forest traffic infrastructure on steep terrain and inaccessible areas because the timber is no longer readily available.

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SAŽETAK

Optimiziranje primarne otvorenosti šuma promatrano je sa stajališta inteziteta gospodarenja njima i terenskih, odnosno reljefnih karakteristika određenog šumskog područja. Proces optimiziranja primarne otvorenosti šuma je prvi dio procesa planiranja primarne šumske transportne infrastrukture, a drugi dio je projektiranje novih trasa primarne transportne infrastrukture. Ovaj proces je neophodan, jer trenutačna primarna otvorenost šuma u BIH omogućava tek ekstenzivno gospodarenje šumama. Visoke šume s prirodnom obnovom odabrane su za optimizaciju primarne otvorenosti, zbog toga što je ova kategorija šuma najvrijednija s kvantitativnog i kvalitativnog gledišta drvne mase. Planiranje primarne transportne infrastrukture podrazumijeva: analizu trenutačne primarne otvorenosti visokih šuma s prirodnom obnovom, određivanje optimalne gustoće primarne šumske transportne infrastrukture, definiranje pogodnosti šumskog područja za gradnju primarne transportne infrastrukture na osnovi višekriterijske analize i projektiranje novih trasa primarne šumske transportne infrastrukture kao nadogradnja trenutačne. Optimiziranje primarne otvorenosti brdskih i planinskih visokih šuma s prirodnom obnovom obavljeno je u dvije gospodarske jedinice, GJ Prosara i GJ Bobija-Ribnik. Korištena je AHP metoda višekriterijske evaluacije i GIS. Određena je optimalna gustoća primarne šumske transportne infrastrukture od 24, odnosno 26 m/ha za prvu odnosno drugu jedinicu, što će omogućiti normalan intezitet gospodarenja visokim šumama u odabranim GJ.

KLJUČNE RIJEČI: primarna šumska transportna infrastruktura, GIS, višekriterijska analiza

HRVATSKA KOMORA
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AKUTNO ODUMIRANJE HRASTOVA (AOH) – NOVA KOMPLEKSNA BOLEST NA HRASTU CRNIKI (*Quercus ilex* L.) I MOGUĆNOSTI ŠIRENJA NA OSTALE VRSTE HRASTOVA U HRVATSKOJ

ACUTE OAK DECLINE (AOD) NEW COMPLEX DISESE ON HOLM OAK (*Quercus ilex* L.) AND POSSIBILITIES OF SPREAD ON OTHER OAK SPECIES IN CROATIA

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SAŽETAK

U radu se prikazuje pregled dosadašnjih saznanja o Akutnom odumiranju hrastova (AOH), u svijetu opisanom kao AOD (Acute oak decline). Ova polimikrobna bolest je nedavno otkrivena u Hrvatskoj (2021. godine) na poluotoku Pelegrin (otok Hvar), gdje se na stablima hrasta crnike zadnjih nekoliko godina javljaju tipični simptomi: sušenje vrhova krošnje koje prate uzdužne raspukline kore, gdje istodobno ispod kore dolazi do odumiranja tkiva u obliku crnih nekroza. U kasnijoj fazi javljaju se i tekline te se vide izlazne rupe kukaca, a stablo nakon 3-4 godine odumire. Bolest se širi sa stabla na stablo, a krajnja posljedica je masovno sušenje. Uzročnici odumiranja tkiva pod korom su patogene bakterije *Brenneria godwinii*, *Gibbsiella quercinecans* i *Lonsdalea britannica*, a njihovi mogući prijenosnici su krasnici *Agrilus sulcicolis* i *A. olivicolor*. AOH je do sada opisana u Ujedinjenom kraljevstvu, Latviji, Španjolskoj, Iranu i Švicarskoj. Važnost prvog nalaza AOH u Hrvatskoj je što hrast crnika kao autohtona vrsta ima posebno značenjej za Mediteranske šume, a k tome su po prvi puta nađene i vrste krasnika koje do sada nisu potvrđene kao vektori AOH. Posebno se naglašava rizik prijelaza AOH na kontinentalne šume hrasta lužnjaka i kitnjaka, jer za razliku od svih dosadašnjih nalaza AOH u svijetu, lužnjakove i kitnjakove šume u Hrvatskoj su jedine koje su već godinama izložene napadima hrastove mrežaste stjenice (*Corythucha arcuata*). Moguća kombinacija hrastove mrežaste stjenice i AOH mogla bi biti iznimno opasna. Stoga se naglašava promptna primjena mjera zaštite, posebice preventivnih te važnost znanstvenih istraživanja.

KLJUČNE RIJEČI: hrast lužnjak, hrast kitnjak, *Quercus* spp., *Agrilus sulcicollis, Agrilus olivcolor*, *Agrilus biguttatus*, klimatske promjene

UVOD
INTRODUCTION

Kronično odumiranje hrastova je sindrom u kojem više negativnih čimbenika često simultano svojim djelovanjem prouzrokuje sušenje kroz dugo razdoblje. Ovaj fenomen poznat kao „umiranje hrastovih šuma“ poznat je više desetljeća u Hrvatskoj i razlikuje se od akutnog odumiranja, prilikom kojeg dolazi do brzog odumiranja s vrlo specifič-

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nim simptomima, djelovanjem određenih negativnih čimbenika. Akutno odumiranje stabala hrasta crnike (*Quercus ilex* L.) prvi je puta zamijećeno na poluotoku Pelegrinu (otok Hvar), gdje su se još 2019. godine sušila pojedinačna stabla, kao i grupe stabala. Prvo se javlja sušenje vrhova krošnje praćene uzdužnim raspuklinama kore i lezije, a ispod kore dolazi to odumiranja tkiva kambja i ksilema u obliku crnih nekroza, za koje je utvrđeno da su im uzročnici tri vrste patogenih bakterija: *Brenneria godwinii*, *Gibbsiella quercinecans* i *Lonsdalea britannica* (Pernek i sur. 2022). U kasnijoj fazi bolesti javljaju se i tekline uz koje se vide izlazne rupe kukaca. Kukci su mogući prijenosnici bakterija, a za sada su nađene dvije vrste krasnika (Coleoptera, Buprestidae): *Agrilus sulcicolis* Lacord. i *A. olivicolor* Kiesw. Ova polimikrobna bolest je potpuno nova kompleksna bolest hrastova u Hrvatskoj za koju predlažemo naziv „Akutno odumiranje hrastova“ (AOH), od engleske izvedenice „Acute oak decline“ (AOD) (Denman i sur., 2014). Širenje AOH na području Mediterana je izgledno, ali njegovo širenje na kontinentalne šume hrastova nije isključeno s obzirom da su lužnjak (*Q. robur* Matt.) i kitnjak (*Q. petraea* L.) glavni domaćini (Denman i sur., 2014).

U ovom radu prezentira se pregled saznanja koja postoje o AOH, o pojavama i štetama na hrastovima u europskim razmjerima, o dosadašnjim saznanjima, te o načinu širenja. Cilj je upozoriti na rizike širenja u Hrvatskoj te dati prijedlog mjera koje treba poduzeti kako bi se ono spriječilo, posebice iz smjera Mediterana na kontinent, a posljedice napada ublažile.

ŠTO JE AOH?
WHAT IS AOD?

AOH je polimikrobna bolest povezana s jakim napadom dendropatogenih bakterija koje izazivaju nekrozu tkiva pod korom, pri čemu dolazi do raspada provodnog sustava ksilema i floema. Stabla obično odumiru 3-4 godine od pojave prvih simptoma. AOH je prvi puta opisana u Ujedinjenom

Slika 1. Simptomi „Akutnog odumiranja hrastova“ a) lezije i uzdužne raspukline na kori hrastova b) odumiranje finih grana na vrhu krošnje c) crne nekroze pod korom hrastova d) tekline na kori e) izlazne rupe krasnika f) terminalna faza i odumiranje stabla

Figure 1. Symptoms of “Acute oak decline” a) lesions and longitudinal cracks in the oak bark b) dieback of fine branches at the top of the crown c) black necrosis under the oak bark d) swollen lesions on the bark e) exit holes of beetles f) terminal phase and tree death

kraljevstvu u 80-tim godinama 20-tog stoljeća, a nakon toga potvrđena je u Latviji, Španjolskoj, Iranu i Švicarskoj (Brady i sur., 2016, Brady i Cotingho, 2021). Postoje indicije da je bolest prisutna i u Austriji, Franuskoj, Nizozemskoj i Poljskoj (Carrie Brady - osobna komunikacija). U većini slučajeva nekrozu tkiva i tekline izazivaju dvije vrste bakterija *Brenneria goodwinii* i *Gibbsiella quercinecans*, dok se vrsta *Lonsdalea britannica* sporadično spominje u Engleskoj (Denman i sur., 2017). U Hrvatskoj je na otoku Hvaru potvrđen nalaz svih triju vrsta (Pernek i sur. 2022).

Prije odumiranja napadnutog stabla mogu se naći izlazne rupe krasnika, prepoznatljive po D-obrisu. Do sada se sa AOH bez iznimke povezivala vrsta *A. biguttatus* Fab. (Denman i sur., 2016; 2017; Brown i sur., 2017), iako je u pokusnim plohama sa feromonskim klopkama uz vrste *A. biguttatus* sporadično nađena i vrsta *A. sulcicolis.* Uloga krasnika i drugih ksilofaga u prenošenju AOH do sada nije u potpunosti razjašnjena, ali je dokazano kako nekrotično tkivo s bakterijama kairomonski privlači krasnika *A. biguttatus* (Brown i sur., 2017).

AOH SIMPTOMI
AOD SYMPTOMS

Prvi simptomi napada AOH su uzdužne raspukline kore (Slika 1a) te sušenje grana na vrhu krošnje (Slika 1b). Ispod kore se nalazi nekrotično tkivo, crne boje i neugodnog mirisa (Slika 1c), koje u kasnijoj fazi zahvaća čitavo stablo (Slika 1d). U drugoj i trećoj godini sušenje se intenzivira, pri čemu odumire sve veći dio krošnje. Treće ili četvrte godine na stablu se pojavljuju tekline (Slika 1d) i izlazne rupe krasnika (Slika 1e), a nakon toga stablo odumire (Slika 1f) (Brown et al., 2016; 2017). Stablo odumire zbog raspada provodnog sustava u floemu i ksilemu.

AOH DOMAĆINI
AOD HOSTS

AOH je u Velikoj Britaniji do sada uzrokovalo velike štete na autohtonim hrastovima *Quercus robur* Matt. i *Q. petraea* L. (Denman et al., 2014). U Španjolskoj je AOH potvrđeno na crniki i pirinejskom hrastu (*Q. pyrenaica* Willd.) (Brady i sur. 2010), a u Švicarskoj na lužnjaku, ceru (*Q. cerris* L.), meduncu (*Q. pubescens* Willd.) te na crvenom hrastu (*Quercus rubra* L.) (Ruffner i sur. 2020). S obzirom da *A. biguttatus* dolazi na svim spomenutim hrastovima, putevi prijenosa bakterija postoje (Moraal and Hilszczanski, 2000), te je širenje AOH ponajprije na hrast medunac vrlo izvjesno. S gleddištaa drveća koje se često može naći u parkovima, zanimljiv je nalaz na alohtonoj vrsti, crvenom hrastu.

DOSADAŠNJA ISTRAŽIVANJA AOH U HRVATSKOJ
RESEARCH OF AOD IN CROATIA

Na poluotoku Pelegrinu AOH je nađen isključivo na stablima hrasta crnike koja su većim dijelom odumrla, dok su druge vrste drveća, kao npr. zelenika (*Phillyrea* spp.) zdrave bez ikakvih simptoma. Na temelju intenzivnog istraživanja uzroka bolesti stabala hrasta crnike sa do sada nepoznatim simptomima u Hrvatskoj u 2021. godini, te informacijama sakupljenim kroz 2019. i 2020. godinu, dosadašnje istraživanje bavilo se sljedećim pitanjima: i) Identifikacija uzročnika patoloških promjena u kambiju kambija (mikološke, bakteriološke analize, ii) Identifikacija vrste krasnika nađenih u stablima (molekularne analize). Istraživanjem i laboratorijskim analizama konačno je utvrđeno kako su uzročnici sušenja stabala hrasta crnike tri vrste patogenih bakterija: *B. godwinii*, *G. quercinecans* i *L. britannica* (Pernek i sur. 2022). Iz trupčića pohranjenih u insektarije entomološkog laboratorija Hrvatskog šumarskog instituta izašle su dvije vrste krasnika: *A. sulcicolis* i *A. olivicolor* (Pernek i sur. 2022). Mehanizam širenja ovog bakterijskog kompleksa nije utvrđen, no vektori bi vrlo vjerojatno mogli biti upravo krasnici.

Seciranjem kompletnog stabla hrasta crnike visine oko 5 m, koje je imalo jasno izražene simptome AOH, traženi su dijelovi u kojima se odvija patološke promjene provodnog sustava te gdje se nalaze izlazne rupe krasnika, pri čemu je utvrđeno da je stablo u potpunosti napadnuto, od pridanka preko debla, pa sve do grana u krošnji (Slika 2).

MOGUĆNOSTI ŠIRENJA AOH U HRVATSKOJ
POSSIBILITY OF AOD SPREADING IN CROATIA

Istraživanja su pokazala kako se bolest prostorno širi prijelazom sa stabla na stablo (Denman i sur. 2014). Zaražena područja je stoga važno kartirati kako bi se bolest mogla pratiti i utvrditi način i smjer te prosječno vrijeme širenja. Za sada se procjenjuje kako se AOH još nije proširio izvan otoka Hvara. Za sada je poznato kako se bolest od 2019. do na 2021. proširila na samom mjestu prvog nalaza (Slika 3.). Na rubovima područja sušenja crnike u ljeto 2021. detaljno su pregledana stabla koja nisu pokazivala simptome sušenja. Željelo se utvrditi je li bolest već zahvatila i naizgled zdrav dio šume, odnosno koliko vanjski simptomi daju uvid u zarazu AOH. Utvrđeno je da naizgled potpuno zdrava stabla hrasta crnike na rubu zaraženog pojasa, iako ne pokazuju jasno uočljive simptome, primjerice uzdužne raspukline kore, ispod kore imaju crne nekroze manjeg intenziteta. Ovo indicira da se zaraza aktivno širi i predstavlja rizik za kompletan poluotok Pelegrin (Slika 3), ali i da je prijenos bolesti na druge otoke ili na kontinent moguć.

Slika 2. Pregled stabla sa simptomima AOH a) rekonstrukcija sekcija stabla b) poprečni presjek debla s vidljivim nekrozama u floemu i ksilemu c) nekroze ispod kore na deblu d) nekroze ispod kore na granama u krošnji

Figure 2. Examination of the tree with symptoms of AOD a) reconstruction of tree sections b) cross section of the trunk with visible necrosis in the phloem and xylem c) necrosis under the bark on the trunk d) necrosis under the bark on branches in the canopy

Prema dosadašnjim istraživanjima, širenje AOH signifikantno je korelirano s vlagom i temperaturom, što znači da će smjer širenja bolesti ići u suše dijelove i područje viših temperatura te dužih vegetacijskih razdoblja. Također je vjerojatno da će se bolest prije pojaviti u području atmosferske polucije, jer je utvrđena korelacija sa dušikovim oksidom (NOx) i sumporom (https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/acute-oak-decline/acute-oak-decline-aod-incidence-and-distribution/). Ova saznanja važna su za izradu prognostičkih modela, što je dalje važno za procjene rizika i pravovremenih primjena mjera suzbijanja.

Slika 3. Masovno sušenje hrasta crnike na poluotoku Pelegrin (sive krošnje su od hrasta crnike, zelene su uglavnom zelenika, na vrhu su zelena borova stabla)

Figure 3. Mass dieback of holm oak on the Pelegrin peninsula (gray canopies belong to holm oak, green are mostly Phillyrea spp., and on top are green pine trees)

MJERE SUZBIJANA
CONTROL MEASURES

Preventivne mjere – *Preventive measures*

Iako je AOH u Hrvatskoj za sada utvrđeno isključivo na hrastu crniki, te lokalno na otoku Hvaru, svako sprječavanje širenja bolesti je izravno i mjera protiv širenja bolesti na šire područje hrastovih šuma hrvatskog priobalja, kao i područje hrasta lužnjaka i kitnjaka. Ove dvije gospodarski važne vrste još su od 2013. godine na udaru neprestanih napada hrastove mrežaste stjenice, *Corythucha arcuata* Say (Hemiptera, Tingidae) (Hrašovec i sur. 2013). Napadi postepeno naizgled jenjavaju i za sada nisu letalni (Kovač i sur., 2021), no pitanje je kakav učinak bi mogla imati kombinacija stjenice i AOH.

Predlaže se uspostava monitoringa AOH na teritoriju Republike Hrvatske u dijelovima u kojima pridolaze hrastove šume, koji bi obuhvatio vizualni pregled temeljem poznatih simptoma u mediteranskim šumama hrasta crnike (Slika 2), te po potrebi proširiti ih na ostale hrastove. Poznavanje preferencija za širenje AOH omogućilo bi izradu prognostičkih karata važnih za preventivne mjere zaštite. Takvo proaktivno gospodarenje šumama značilo bi da se u zonama visokog rizika širenja AOH moraju poduzeti sve radnje koje će spriječiti širenje u nezaraženo područje. Također bi se u novim područjima pojave AOH trebao uvesti monitoring mogućih vektora (za sada su to krasnici, no moguće je da bi prijenosnici mogle biti i druge ksilofagne vrste) feromonskim klopkama.

Suzbijanje vektora – *Control of vectors*

Glede činjenice da zaštitne mjere protiv bakterija ne postoje, a da je širenje od stabla do stabla dokazano i jasno vidljivo na Hvaru, predlaže se da se mjere suzbijanja usmjere prema prijenosniku (vektoru), odnosno krasnicima. Jedina mjera koja bi mogla polučiti rezultate za sprječavanje širenja fronte AOH je kontrolirana sječa sigurnosne zone na samom rubu pronalaska simptoma, na udaljenosti od barem 100 m, te spaljivanje zaraženog materijala u tom pojasu. Cilj je uništiti izvore zaraze, stoga bi u tom smislu kontrolirano spaljivanje šume polučilo apsolutno najbolju mjeru zaštite. Međutim, prije primjene drastičnih mjera važno je dokazati gdje se AOH nalazi, odnosno je li prisutno i u drugim područjima osim Hvara.

RASPRAVA I BUDUĆA ISTRAŽIVANJA
DISSCUSION AND FUTURE PROSPECTS

Negativni učinci klimatskih promjena odražavaju se kroz pomicanja klimatskih zona, te porast ekstremnih klimatskih događaja i povećanje temperatura i suše (IPPC, 2014). Područje mediteranskog bazena smatra se „hot spot-om" klimatskih promjena (Giorgi 2006), pri čemu je naglašena aridifikacija (Pinol et al. 1998; Sillmann et al. 2013, Vicente-Serrano, et al. 2010), a predviđa se kako će te šume biti zbog toga izložene jačem stresu, što će utjecati na prirast i opstanak šuma (Vicente-Serrano, et al. 2010). Peñuelas i Sardans (2021) smatraju kako izravne posljedice aridifikacije proizlaze iz limitirane otpornosti mediteranskih šuma na sušu, a u kombinaciji s neizravnim štetama (češća i intenzivnija pojava štetnih organizama i požara) predstavljaju prijetnju budućnosti mediteranskih šuma. Sukladno tim predviđanjima, nagle promjene i štete od biotičkih čimbenika nisu neočekivane, što potvrđuju i novija istraživanja i neuobičajene gradacije štetnika poput mediteranskog potkornjaka (Pernek et al. 2019) ili borovog prelca u Dalmaciji (Matek i Pernek 2018). Tome se može pribrojati i ovdje opisana

polimikrobna bolest AOH. Bolest je prema dosadašnjim saznanjima u Hrvatskoj isključivo prisutna na području prvog nalaza na otoku Hvaru na hrastu crniki i tu se širi, ali nije poznato je li se već proširila ili je već prisutna u ostalom području Dalmacije. Širenje u druga područja predstavlja višestruku opasnost: i) širenje u arealu hrasta crnike, ii) širenje u submediteranske šume hrasta medunca, iii) širenje u kontinentalne šume hrasta lužnjaka i kitnjaka.

Poučeni stanjem na području nalaza AOH na Hvaru, širenje bolesti u arealu hrasta crnike predstavlja ozbiljan rizik masovnog sušenja te autohtone vrste. Poznato je kako sve više vrsta izumire i to u geološki kratkom intervalu, što se posebice očituje posljednjih nekoliko desetljeća, te se opravdano strahuje da se nalazimo u razdoblju masovnog izumiranja vrsta (Barnosky i sur. 2011). U tom kontekstu AOH je posebno osjetljivo pitanje na Mediteranu radi obnove autohtonih vrsta, tim više što se obnova autohtonih ekosustava i poboljšanje njihovog upravljanja smatra temeljnom mjerom zaštite biološke raznolikosti i ublaživanja sve izraženijih klimatskih promjena (Griscom i sur. 2017).

Što se tiče širenja AOH u submediteransko područje hrasta medunca, iako nema saznanja kako bi se AOH odrazio na šumu u tom području, poznato je da je hrast medunac domaćin mogućim vektorima AOH te je zaraza ovih šuma također moguća.

Šume hrasta lužnjaka i kitnjaka u Hrvatskoj su već godinama pod konstantnim napadom hrastove mrežaste stjenice. Štete bi mogle biti enormne, a pitanje je koliko bi kurativna reakcija u slučaju jakog širenja AOH bila uspješna. Također je važno napomenuti kako se odumiranje hrasta lužnjaka bilježi već više od stoljeća, a prve pretpostavke o čimbenicima koji ga uzrokuju su razmatrale djelovanje samo jednog uzročnika (npr. pepelnice ili golobrsta gubara). S vremenom su te jednostavne hipoteze zahvaljujući opsežnim istraživanjima evoluirale u shvaćanju pojave odumiranja hrasta lužnjaka kao složenoga procesa, gdje u različitim fazama i različitim intenzitetima sudjeluje velik broj biotskih i abiotskih čimbenika koji svojim međudjelovanjem (interakcijom) uzrokuju odumiranje pojedinačnih stabala ili sastojina. Prema najnovijim znanstvenim spoznajama i modernim konceptualnim okvirima za svaki se pojedinačni slučaj sušenja stabla treba utvrditi zasebni kompleks pripremnih, poticajnih i terminalnih čimbenika koji utječu na tu pojavu (Manion 1991, Dubravac i Dekanić, 2009., Dekanić i dr. 2009). Mnogostruke štetne posljedice odumiranja stabala najviše se očituju u srednjedobnim, starijim i starim sastojinama hrasta lužnjaka (Dubravac i dr. 2011.). Smanjenjem broja stabala hrasta lužnjaka po jedinici površine narušava se sklop i pada obrast, čime se narušavaju sastojinska klima i struktura sastojina, a čestim ulascima mehanizacije povećavaju se potencijalno negativni utjecaji na tlo i preostala stabla u sastojini (Dubravac i dr. 2011.). Odumiranje pojedinačnih stabala i učestale sječe ostavljaju mnogobrojne negativne posljedice na šumske ekosustave koje su s ekološkog i uzgojnog stajališta puno veće od stvarnih financijskih gubitaka, posebice ako se promotre u kontekstu prirodne obnove. Stoga rizik širenja i etabliranja AOH u kontinentalnom dijelu Hrvatske treba shvatiti krajnje ozbiljno, jer su hrast lužnjak i kitnjak vrste najosjetljivije na AOH (Denman i sur. 2014).

Krasnik koji se uobičajeno spominje u kontekstu AOH bez iznimke je vrsta *A. biguttatus*. Zanimljivo je da na Hvaru taj krasnik u dosadašnjem istraživanju uopće nije nađen u drvetu, već su nađene druge dvije vrste *A. sulcicolis* i *A. olivcolor*. To otvara pitanje uloge tih specifičnih vrsta krasnika u procesu sušenja crnike, njihove biologije i načina eventualnog prijenosa bakterija.

Za sada se ne može sa sigurnošću utvrditi zašto se baš na tom dijelu otoka dogodio AOH koji nikada do sada nije opisan u Hrvatskoj. U kompleksu polimikrobnih uzročnika treba također istražiti i mikološki kompleks te vidjeti u kojoj mjeri on djeluje na mortalitet.

Suočeni s novom ozbiljnom prijetnjom za hrastove šume, u sljedećem razdoblju bit će važno prilagoditi se i razraditi moguće protumjere sprječavanja širenja AOH ili ublažavanja većih štetnih posljedica. S obzirom na već spomenute praznine u znanju i specifičnosti u Hrvatskoj, pitanja koja se nameću oko bolesti AOH važno je rasvijetliti te provesti sustavna znanstvena istraživanja ove kompleksne bolesti hrastova koja je prisutna u Hrvatskoj.

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iberica subsp. nov. and *Lonsdalea quercina* subsp. *britannica* subsp. nov., *emendation* of the description of the genus *Brenneria*, reclassification of *Dickeya* dieffenbachiae as *Dickeya dadantii* subsp. *dieffenbachiae* comb. nov., and emendation of the description of *Dickeya dadantii*. International Journal of Systematic Evolutionary Microbiology, 62: 1592–1602.

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SUMMARY

The paper presents an overview of current knowledge on Acute Oak Decline (AOD), a polymicrobial disease that was recently discovered in Croatia (in 2021) on the Pelegrin peninsula (island of Hvar). In the last few years typical symptoms have appeared on holm oak trees: dieback of the top of the tree crown, followed by appearance of longitudinal cracks in the bark and black tissue necrosis in the form of black necrosis under the bark. At a later stage, swollen lesions with exit holes of insects on tree stems appear, and after 3-4 years tree dies. The disease spreads from tree to tree, resulting in mass dieback. The causes of tissue necrosis under the bark are pathogenic bacteria *Brenneria godwinii*, *Gibbsiella quercinecans* and *Lonsdalea britannica*, and their possible vectors are jewel beetles *Agrilus sulcicolis* and *A. olivicolor*. AOD has so far been described in the United Kingdom, Latvia, Spain, Iran and Switzerland. The specificity of the first AOD finding in Croatia is that holm oak as a native species has a special significance for the Mediterranean forests, and for the first time other species of jewel beetles that have not been found as AOD vectors have been detected. The risk of AOD transition to continental pedunculate oak and sessile oak forests is particularly concerning, because unlike all previous AOD findings in the world, pedunculate and sessile oak forests in Croatia are the only ones that have been exposed to constant attacks of oak lace bug (*Corythucha arcuata*) for years. The possible synergism of oak lace bug with AOD could be extremely dangerous. Therefore, the prompt application of protection measures, especially preventive ones, together with the importance of scientific research is emphasized.

KEY WORDS: pedunculate oak, sessile oak, *Quercus* spp., *Agrilus sulcicollis, Agrilus olivcolor*, *Agrilus biguttatus*, climate change

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MONITORING OF REINTRODUCED RED DEER IN THE AREA OF TARA (WESTERN SERBIA): INCIDENCE OF BARK STRIPPING WITHIN AN ACCLIMATISATION ENCLOSURE AND POSTRELEASE MOVEMENTS

MONITORING REINTRODUCIRANOG JELENA OBIČNOG NA PODRUČJU TARE (ZAPADNA SRBIJA): OPSEG GULJENJA KORE U PRIHVATILIŠTU I KRETANJE POSLIJE ISPUŠTANJA

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SUMMARY

The modern approach in the development of programs for the reintroduction of red deer was applied for the first time in Serbia. We compared the most important planned and implemented activities in the period 2018-2021, and assessed the results achieved in the Mt. Tara area. The plan was to hold the red deer (5♂ + 15♀) in the acclimatisation enclosure for several months and release them into the selected favourable area (150 km^2) during three consecutive years. Bark stripping occurred mainly on thinner common hazel stems of coppice origin (≤ 9.9 cm). Total mortality among the 72 red deer that were transported to the acclimatisation enclosure was 8.3%. The longest movement of a 4-year-old female (held for 15 weeks) was 24 km. During the study period, no bark stripping was observed outside the acclimatization enclosure, nor were any deaths of the released red deer registered. In the period 2019-2021, 74 red deer were released from the acclimatization enclosure into the Mt. Tara area, which is about 60% of the estimated capacity of the selected favourable area.

KEY WORDS: Cervus elaphus, reintroduction, population, management, GPS collar

INTRODUCTION
UVOD

In the past, red deer (*Cervus elaphus* L.), as an indigenous species was present in large numbers in many forest complexes in today's central Serbia, whose forest cover is about 37%, with mostly coppice forests occupying 66% or 1.38 million hectares (Gačić et al., 2020). According to the data from the statistical survey on hunting (Form LOV-11, municipal level, www.stat.gov.rs), in the spring of 2019 the estimated number of red deer was 6,268 individuals, of which 2,056 individuals or 32.8% were in Central Serbia: 1,593 individuals in the statistical region of Southern and Eastern Serbia, and 463 individuals in the statistical region of Šumadija and Western Serbia (Fig. 1). More precisely, the to-

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tal recorded culling in 2019/2020 was 94 individuals in these statistical regions (78 and 16, respectively). This clearly indicates that the current status of red deer is not favourable in central Serbia, mainly due to overexploitation (legal and illegal), habitat loss and competition with domestic livestock, which were also the main causes of deer extinction in some parts of Europe (Burbaité and Csányi 2010; Valente et al., 2017).

In the period 2016-2018, a multidisciplinary research was successfully implemented within the SRBREDDEER project, which was initiated and funded by the Forest Administration of the Ministry of Agriculture, Forestry and Water Management. For the first time a modern approach and methodology were applied to determine areas suitable for the reintroduction of red deer in Serbia, as well as to determine the location of acclimatisation enclosure, risk assessment of extinction and minimum viable population after reintroduction, and develop a more efficient monitoring system for red deer populations and their habitats in Serbia (Gačić et al., 2020). One of the main project activities was the collection and analysis of data on previous reintroductions of red deer in Serbia and throughout Europe (e.g. Bojović, 1968; Tomić et al., 2010; Apollonio et al., 2014), with emphasis on errors and factors of the greatest significance for their success or failure. Thanks to that, measures were proposed to improve the ongoing reintroductions in Serbia, not only to improve the survival and reproduction of red deer, but also to make the reintroduction process as economical as possible.

The proposed program for the reintroduction of red deer to the Mt. Tara area (Gačić et al., 2018) was based on the guidelines prepared and adopted by the IUCN/SSC Re-introduction Specialist Group (1998, 2013), as well as on the conclusions from the expert workshop held in Kragujevac (May 26, 2018) within the SRBREDDEER project. Besides this, the spatial context of reintroduction was observed through the specific landscape pattern issues using a structural metric parameter (Kie et al., 2002; Plante et al., 2004). In addition, it is based on the interest and willingness of local hunters and relevant state hunting authorities to provide full and long-term support to this reintroduction in the selected favourable area of Mt. Tara. Therefore, it differs significantly from all previous programs implemented in central Serbia (Hadži-Pavlović, 1986; Novaković, 1999).

The aim of this paper was to compare the most important planned and implemented activities related to the proposed program during the period 2018-2021, and to evaluate the results achieved in the reintroduction of red deer in the Tara area with emphasis on the incidence of bark stripping within an acclimatization enclosure and postrelease movement of red deer.

MATERIAL AND METHODS
MATERIJAL I METODE

Research area – *Područje istraživanja*

The selected favourable area for reintroduction was central part of the Tara mountain massif (Fig. 1) on the area of 150 cels 1 km × 1 km squares. The altitude ranges from 424 to 1,544 m a.s.l., but the altitudinal belt of 900-1,300 m occupy about 119 km^2, or 79.3% of its total area.

The acclimatisation enclosure is located in the central part of the favourable area (Fig. 2), which mostly belongs to two hunting grounds. The acclimatisation enclosure occupies 3.63 ha (altitude about 1,100 m a.s.l.), of which most are forests (1.90 ha or 52.3%), followed by meadows and pastures (1.27 ha or 35.0%), forest land (0.18 ha), wetland (0.27 ha), while it also contains two wooden huts (0.01 ha). The parent rock is limestone, which forms smaller or larger ridges in some parts of the forest.

According to Gačić et al. (2018) 150 km^2 was the smallest possible area relevant for the assessment of red deer habitat, where the newly established red deer population has a realistic chance of remaining as a compact whole after reintroduction. In addition, we analyzed the position of the

Figure 1. Research area
Slika 1. Područje istraživanja

acclimatization enclosure in relation to the characteristics of the neighboring forests including state forests (managed by state forest company - approx. 7,550 ha and Tara National Park - approx. 4,180 ha) and Church forests (approx. 360 ha). Areas under high forests range from 40.2 to 97.8%, while non-overgrown areas are rare, mostly barren land (range 0.3-18.1%). The main tree species are common beech (*Fagus sylvatica* L.), sessile oak (*Quercus petraea* / Matt./ Liebl.), Austrian pine (*Pinus nigra* J. F. Arnold), Norway spruce (*Picea abies* /L./ H. Karst), Scots pine (*Pinus sylvestris* L.), silver fir (*Abies alba* Mill.) and European white birch (*Betula pendula* Roth.). Numerous rivers (Đetinja, Bratešina, Kamišina and Rača), as well as numerous streams that have water throughout the year pass through the area, so the hydrographic characteristics are favourable. It is estimated that the current state of the road network in these forest management units does not cause serious habitat fragmentation.

The vegetation period in the research area begins in mid-April and ends in late October. The average annual rainfall is about 1040 mm. A significant part of the annual precipitation is in the form of snow. The first snow appears in September, and the last one in April, sometimes even later. The season with the highest recorded precipitation is summer, followed by autumn, spring and winter. The main directions of wind blowing are northeast and southwest. For further information on the research area and acclimatisation enclosure, see Gačić et al. (2018, 2020).

Methodology – *Metodologija*

Our study is based on a newly established population of 74 red deer released in the Mt. Tara area during 2019 (n = 22), 2020 (n = 32) and 2021 (n = 20), from five localities: 1. Dubašnica, 2. Fruška gora National park, 3. Bukovik, 4. Plavna and 5. Kozara (Fig 1.). The data on the number and structure (sex and age) of released red deer were collected from the records of the Forest Directorate (Ministry of Agriculture, Forestry and Water Management) and PE "Vojvodinašume". Animals were from enclosures.

During the first year of red deer reintroduction, six females were translocated from eastern Serbia, a fenced part called Dubašnica within the hunting ground Zlotske šume - Crni vrh, three of which died during transport on March 17, 2019, and one after a few days, most likely due to the stress of capture and long transport. A month later, 17 individuals were translocated from Vojvodina (4 males, 7 females and 6 calves), which originate from Hungary but were temporarily kept in quarantine at the Ravne location within the hunting ground of Fruška Gora National Park.

During the second year (January 28, 2020), four females were translocated from a fenced area called Košuta inside the Bukovik hunting ground in southern Serbia, one of which died a few days after arrival. Then, six males from Vojvodina, originating from the Plavna hunting ground (February 15), as well as 18 individuals (2 males, 7 females and 9 calves) from Fruška gora National Park (March 23) were also translocated.

During the third year, six males were translocated from the hunting ground Plavna (February 10, 2021), one of which died a few days after arrival. A month after that, four females and two calves were translocated from the hunting ground Plavna (March 27) and one male, seven females and one calf from the famous hunting ground Kozara in Vojvodina (March 29).

Upon arrival, red deer were placed in an acclimatisation enclosure at Jezerine, a location 14.4 km away from the main road Užice - Višegrad, which also had the role of a temporary holding quarantine. The plan was to hold the red deer in the acclimatisation enclosure for several months to allow them to recover from the trip and to acclimatize to their new habitat, and release them into the selected favourable area (150 km^2) during three consecutive years between July 20 and August 15, depending on weather conditions and calf development. However, the length of the holding period varied due to an unplanned release in 2021 resulting from a damage to the fence caused by brown bear – *Ursus arctos* L. (from February 10 to the beginning of May) until the planned release after calving in 2019 (April 17 to July 29) and 2020 (January 28 to June 25). In both cases, the holding period lasted for several months, which is a technique defined by some authors as soft release (Rosatte et al., 2007; Ryckman et al., 2010). During captivity, as well as after release, red deer were provided with hay, maize and rock salt.

The reintroduced red deer were monitored in a way that does not interfere with its normal activities and does not lead to domestication. We used quality equipment for day and night observation (Swarovski SLC 10 × 42, Pulsar CORE FXQ 50, camera traps Ltl Acorn, Spromise and Seissiger), while five individuals (4♀ + 1♂) were equipped with GPS collars (Lotek LifeCycle 500 Pro Collar) during disease-testing protocol in quarantine of origin (Ravne - Fruška gora National Park) in April 2019. These individuals were then loaded into a livestock trailer and transported to the acclimatisation enclosure in the area of Tara.

Other participants in the monitoring were employees of local hunting association ("Aleksa Dejović", Užice) and Tara National Park (Bajina Bašta), who used camera traps and personally collected records of red deer in the field, or collected records from the local people. All records from the Đetinja hunting ground were without data on geographical coordinates, so they were not included in the statistical analysis. We had a total of 27 complete records, of which 26 were from the Tara National Park hunting ground and

one from the Soko hunting ground. Additionally, we had 14 records in the period from August 15 to November 9, 2019, which were obtained from a 4-year-old female equipped with GPS collar number 607. The straight-line dispersion distance from the acclimatisation enclosure was calculated. The difference between the mean dispersion distances in 2019, 2020 and 2021 was tested using one-way ANOVA and the Fisher's LSD test ($P < 0.05$) after log transformation (STATGRAPHICS 16.1). The collected data were mapped and all spatial analyses were performed using ArcGIS 10.3 Package.

Incidence and intensity of bark stripping caused by red deer within the acclimatisation enclosure were determined from 18 to 20 September, 2020. The definition of incidence is the percentage of damaged trees in an area, and the intensity is the severity of damage to an individual tree, such as the number or size of bark wounds (Gill, 1992). Trees of high and coppice origin were randomly selected on the entire surface of the forest, so we mostly moved along isohypses. The diameter at breast height was measured (cm) and the position of the tree in the acclimatization enclosure was determined using a Magellan Mobile Mapper 50 4G GPS receiver. The total number of measured trees of high origin (n = 479) was twice smaller than the trees of coppice origin (n = 999). Each individual tree was assessed for all visible bark stripping damage (recent and aged) and was quantified using a five point scale (Mountford, 1997): 0 = no damage (no bark removed); 1 = limited damage (<10% bark removed); 2 = moderate damage (10-50% bark removed); 3 = severe damage (>50% bark removed); and 4 = very severe damage (ring-barked). Utilization intensity (%) was calculated for trees of coppice origin and represents the ratio of debarked stems and all stems in the stump, e.g. some stumps of common hazel (*Corylus avellana* L.) had 30 stems. The median values for damaged and undamaged common hazel trees were compared by the Kruskal–Wallis test.

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

Bark stripping occurred mainly on thinner common hazel stems of coppice origin (≤ 9.9 cm), as well as on thinner aspen, European hornbeam and sycamore stems of high origin (Fig. 2). In total, 1478 stems within the acclimatization enclosure were examined and 301 of them were debarked (20%).

The mean stem girth of coppice and high trees was 5.1 ± 4.6 and 13.7 ± 12.1 cm, respectively. Bark stripped common hazel stems were not significantly thinner than undamaged common hazel stems (Kruskal–Wallis test: KW = 1.10, P = 0.29). We found that middle-aged and quality trees of the main species were not damaged: beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*), sessile oak (*Quercus petrae*), Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and wild cherry (*Prunus avium*). These results indicated that, except properly supplemental feeding, an adequate methodology for the selection of acclimatisation enclosure had been applied, whose habitat quality mitigated the consequences of numerous mistakes made during the implementation of the reintroduction program. During the study period, no bark stripping was observed outside the acclimatization enclosure.

The highest incidence and intensity of bark stripping damage were found on the edge of the forest near the best meadow, where there are two old wooden huts and a feeding station with maize and hay. Utilization intensity was the highest in the part of the forest that is below the best meadow and feeding site, and above the moist soil where the only water source is located (Fig. 3).

Habitat quality at the release site has a high impact on the success of reintroduction, if the number and origin of the inhabited breeding stock are favourable, which includes the degree to which the animals are dispersed from the release

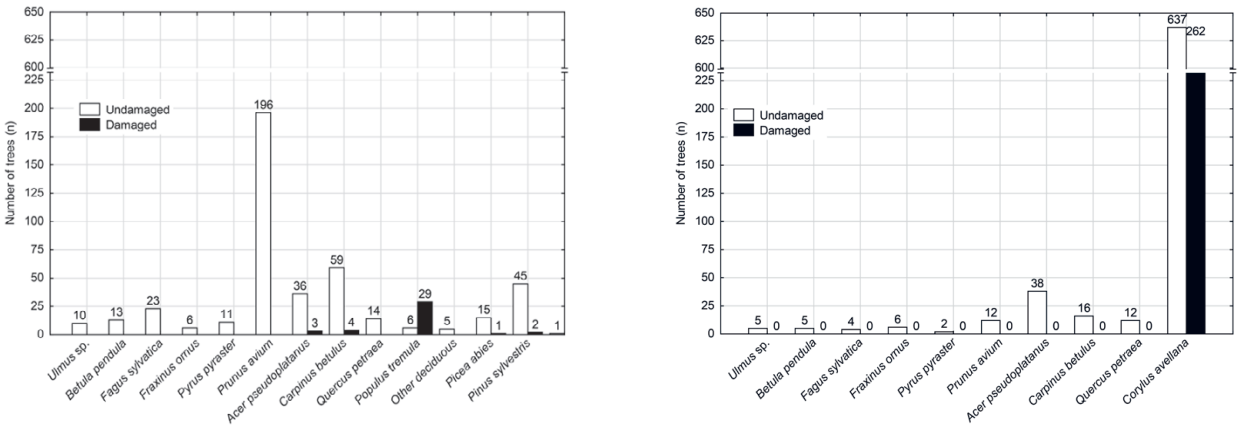

Figure 2. Number of trees per species - left (seed origin), right (coppice origin)
Slika 2. Broj stabala po vrstama drveća - lijevo (iz sjemena), desno (iz panja)

Table 1. Intensity of damage within acclimatisation enclosure in the area of Tara
Tablica 1. Intenzitet guljenja kore u prihvatilištu jelena običnog na području Tare

DBH class *Debljinski stupanj* (cm)	Category (damage score) *Kategorija oštećenja*					Total *Ukupno* (n)
	No *Nema*	Limited *Slab*	Moderate *Umjeren*	Severe *Jak*	Very severe *Vrlo jak*	
			Trees of high origin *Stabla visokog porijekla*			
≤ 9.9	206	8	11	5	11	241
10.0-19.9	139	1	2	1	-	143
20.0-29.9	44	-	-	-	-	44
30.0-39.9	23	-	-	-	-	23
40.0-49.9	13	-	-	-	-	13
50.0-59.9	11	-	-	-	-	11
60.0-69.9	4	-	-	-	-	4
Total *Ukupno*	440	9	13	6	11	479
			Trees of coppice origin *Stabla izdanačkog porijekla*			
≤ 9.9	678	260	-	-	-	938
10.0-19.9	39	2	-	-	-	41
20.0-29.9	12	-	-	-	-	12
30.0-39.9	3	-	-	-	-	3
40.0-49.9	4	-	-	-	-	4
50.0-59.9	1	-	-	-	-	1
Total *Ukupno*	737	262	-	-	-	999

site (Griffith et al., 1989; Yott et al., 2011; Apollonio et al., 2014). The location of the acclimatisation enclosure Jezerine in the Tara area was determined with the participation of numerous experts (from Serbia, Slovenia and Italy) using landscape structure analyses and the common phytocoenological methodology (Gačić et al., 2018). Based on these analyses, four hexagons (the area of each one is 50 ha), were selected, which are sunny during the winter with an average value of 1228 Wh per unit area of 25 m^2. Their landscape structure is complex with over 1120 elements on an area of 200 ha, while the length of the forest edge is about 54 km on an area of 200 ha.

There are pastures of good enough quality on natural meadows in the acclimatisation enclosure Jezerine. They were once mowed to feed livestock, and now various shrub species such as common hazel, blueberry (*Vaccinium myrtillus* L.), forest blackberry (*Rubus* spp.) and wild rose (*Rosa* spp.) appear on them. In addition, the scrub of common hazel is present, mostly as shrubs with several thin and several thicker stems from the stump. In the further surroundings, the share of areas under field crops and orchards was not large. The red deer released within the acclimatisation enclosure removed the bark of several tree species during spring and summer 2020 (Tab. 1). We believe that this can be explained by its significantly smaller total area than projected (3.63 vs 7.29 ha). In addition, in 2020, a higher number of individuals was released (n = 28) compared to the projected optimal number (5♂ + 15♀), which was then further increased in early June by five newborn calves. Unfortunately, there are no detailed data on supplementary feeding within the acclimatization enclosure, especially on the amount of maize suppled on a daily and/or monthly basis, so it was not possible to analyze the impact of this factor on the released red deer behavior.

From 29 July 2019 to 30 November 2021, we obtained 41 red deer locations for the 74 released individuals from the acclimatisation enclosure in the area of Tara (Tab. 2). Approximately 42% of all location estimates were obtained from direct observations, 34% from GPS collars, and the remaining 24% from camera traps, footprints and damage by red deer.

Mean straight-line dispersal distance differed between GPS points and other red deer records in 2019 ($F_{1,18}$ = 288.76, P < 0.05), but GPS points were not obtained in 2020 and 2021 (Fig. 4). The dispersal distance for GPS points (4-year-old female) ranged from 17.30 to 24.23 km (mean ± SD = 21.89 ± 2.47), while for the other pooled records it ranged from 3.09 to 18.44 km (8.97 ± 4.30). The mean straight-line dispersal distance from the acclimatisation enclosure differed between the three study years ($F_{2,24}$ = 5.55, P = 0.01). Red deer during 2020 (11.66 ± 4.61) dispersed farther than red

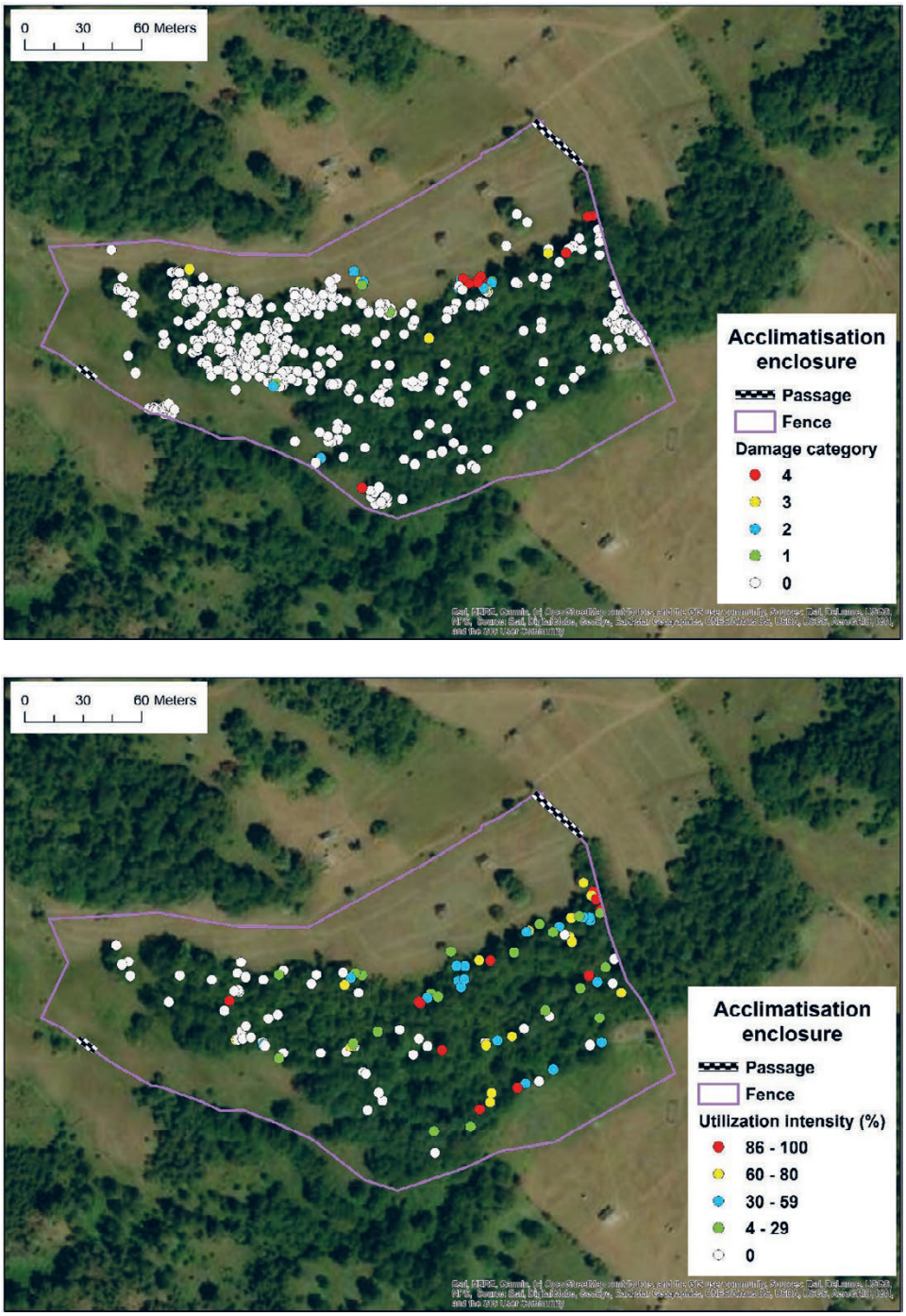

Figure 3. a - shares of trees per damage category (trees of high origin), b - utilization intensity in % (trees of coppice origin)
Slika 3. a - raspored stabala iz sjemena po kategoriji oštećenja, b - prosiječno korištenje (guljenje kore) stabala iz panja

deer in 2019 and 2021 (6.85 ± 1.26 and 7.29 ± 3.76, respectively).

Total mortality among the 72 red deer that were transported to the acclimatization enclosure was 8.3% between 2019 and 2021, of which three females died in the livestock trailer, and three individuals after a few days in the acclimatization enclosure (2♀ + 1♂). During the study period, there were no recorded deaths of released red deer outside the acclimatization enclosure. The fence around the acclimatization enclosure was much weaker than designed (Gačić et al., 2018), due to which free-ranging brown bears and wild boars could enter the enclosure and access the feeding station, even when new groups of red deer were inside and the fence was closed.

Red deer were released from the acclimatization enclosure through two openings in the fence whose length was 10 and 30 m (Fig. 3). Each year, these openings were closed a few days before the transport of the new group, until the day of

Table 2. Dispersal distance from the acclimatization enclosure for released red deer
Tablica 2. Udaljenost od prihvatilišta za jelena običnog naseljenog na području Tare

Record *Zapis* (n)	Date *Datum*	Record description *Opis zapisa*	Distance *Udaljenost* (km)
1	30 July 2019	Camera trap on a brown bear feeding place, 7 ♀ + 1 ♂	5.18
2	end of August 2019	Direct observation (gamekeeper), 2 ♀	6.21
3	3 September 2019	Camera trap on a feeding place, 1 ♂ (with GPS collar)	6.10
4	5 September 2019	Direct observation, 1 ♀	8.61
5	15 September 2019	Direct observation, 1 ♀	7.85
6	2 October 2019	Direct observation, 3 ♀	7.15
7	19 January 2020	Footprint on the ground	17.82
8	18 February 2020	Footprint on the ground	18.44
9	20 April 2020	Camera trap and direct observation (gamekeeper), 3 ♀	12.41
10	21 April 2020	Direct observation (gamekeeper), 1 ♀	8.36
11	24 June 2020	Direct observation (vegetable garden owner), 1 ♀	7.89
12	4 July 2020	Direct observation, 1 ♂	7.77
13	29 July 2020	Direct observation (vegetable garden owner), 1 ♀	10.45
14	end of August 2020	Direct observation, 1 ♀ + 1 ♂	7.59
15	10 September 2020	Browsing by red deer on beech trees	6.74
16	11 September 2020	Direct observation, 1 ♀ + 1 ♂	18.39
17	29 October 2020	Direct observation (hunting ground manager), 1 ♀	12.45
18	31 January 2021	Direct observation, 2 ♀	17.14
19	6 February 2021	Footprint on the ground	4.88
20	5 March 2021	Direct observation, 3 ♀ + 3 ♂	7.78
21	5 June 2021	Direct observation (gamekeeper), 1 ♀	8.21
22	15 July 2021	Damage by red deer on vegetable garden	6.96
23	24 August 2021	Camera trap, 1 ♂	5.69
24	end of August 2021	Direct observation, 1 ♂	7.04
25	end of August 2021	Direct observation, 2 ♀	6.21
26	20 September 2021	Direct observation, 2 ♀	5.95
27	November 2021	Camera trap and direct observation, 3 ♀ + 1 ♂	3.09

their release, so that previously released individuals into the wild (Đetinja hunting ground) could return to the acclimatization enclosure for most of the year. The exception was 2021, when a brown bear destroyed part of the fence, as a result of which the released red deer escaped from the acclimatization enclosure before calving.

Our results obtained in 2019, showed that red deer dispersal occured immediately after release from the acclimatization enclosure, which confirms the results obtained in Ontario, Canada (Yott et al., 2011). The release began in the afternoon of July 29, and on the same day, the first herd of one middle-aged male and 7 hinds left the acclimatization enclosure at around 10:30 pm. Then, this herd was recorded early in the morning of July 30 at 4:27 am on the camera trap in the hunting ground Tara National Park (record no. 1), which was at a 5.2 km distance (straight-line) from the acclimatization enclosure. After 3-4 days, another middle-aged male equipped with a GPS collar, a number of other hinds and three newborn calves came out. Two hinds from eastern Serbia returned to the feeding station in the acclimatization enclosure almost every day during the night, while hinds from Fruška gora National Park and newborn calves were recorded at a site located about 1.5 km from the acclimatization enclosure. The following month, on September 3, 2019 at 2:14 am, a middle-aged male equipped with a GPS collar was spotted on a camera trap at a distance of 6.1 km (record no. 3), but it was returning to the acclimatization enclosure for the next two years.

The distribution of red deer around the acclimatization enclosure was satisfactory, but there were no records with geographical coordinates from the hunting ground Đetinja (Fig. 4). Instead, there are many records obtained using camera traps, which showed that one middle-aged male and three females equipped with GPS collars remained very close to the acclimatization enclosure after release in 2019. In addition, there are some individuals, or smaller herds around the acclimatization enclosure, that have been continuously seen by the guard service, especially after the establishment of three new feeding stations surrounding the acclimatization enclosure.

Unfortunately, 4 GPS collars that were placed on one male and three females did not give the expected results during the study period. One collar did not function after being

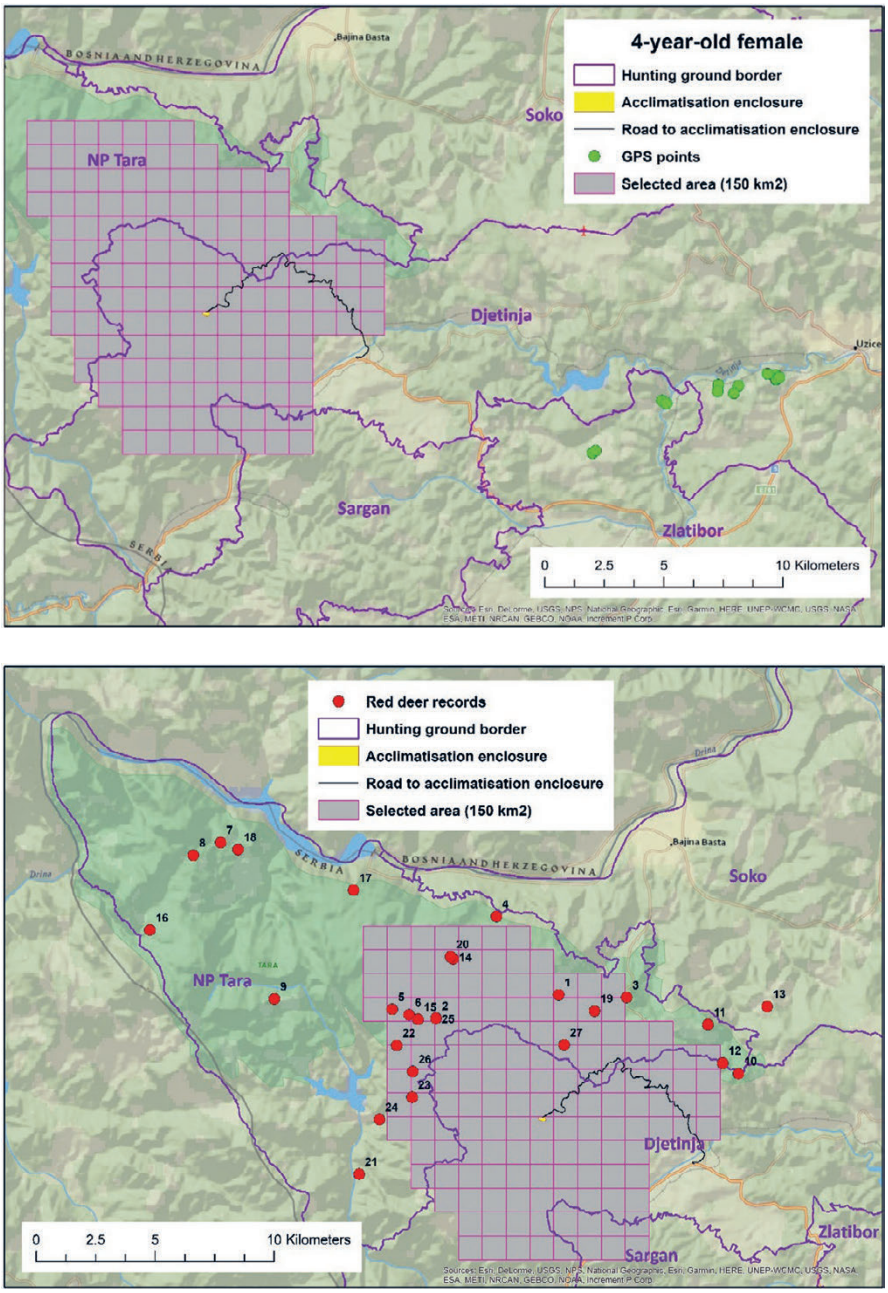

Figure 4. Dispersal distance: a - GPS collar points (n = 14), b - other red deer records (n = 27)
Slika 4. Udaljenost od prihvatilišta: a - točke od GPS ovratnika (n = 14), b - drugi zapisi (n = 27)

placed on the animal, while three collars collected GPS points only while the animals were in the acclimatization enclosure. This can be explained by the inadequate time lag in the dynamics of procurement of the GPS collars (January 2018) and the delay in the start of their application (April, 2019). In addition, there were problems in obtaining 3D locations from the GPS collars due to dense vegetation and steep terrain, which was also reported by many other researchers (e.g. Jung et al., 2018).

We believe that the fidelity of the release area can be explained by its high quality habitat and that the release stock was kept for several months in the acclimatization enclosure, as well as that all released red deer originate from a smaller fenced parts of the hunting ground. Since the released red deer have different origins, with most individuals originating from Hungary (17 in 2019 and 18 in 2020), Vojvodina (6 in 2020 and 20 in 2021), southern Serbia (3 in 2020) and eastern Serbia (2 in 2019), it is plausible to assume that this also influenced the establishment and growth of the population in the Tara area, especially the postrelease movements of individuals.

A large number of the red deer in the area of Tara released from 29 July 2019 to early May 2021 were moving within a 10 km-distance from the acclimatization enclosure (Fig. 4).

The longest movement of a 4-year-old female (held for 15 weeks) was 24 km, when she came very close to the town of Užice together with two other individuals. She stayed there from August 15 to November 9, 2019 (after that, GPS collar failed), which was a dispersal event contrary to all our predictions. The cause of this movement may be wolf harassment, as a few days after the opening of the fence near the acclimatization enclosure (≈ 2.5 km), one female from a pack of three wolves was culled by the guard service. There may also be a need for water and better food resources during the stay in the enclosure, because this new habitat near Užice is located at an altitude of 600 to 900 m a.s.l., along the Đetinja River and various agricultural crops in a deciduous forest setting.

Red deer uses space depending on the impacts of various factors, such as abiotic (topography and climate) and anthropogenic (forest characteristics, supplementary feeding, roads and hiking trails), but also historical events and management in the past (Stergar and Jerina, 2017). Reaserch in Slovakia (Kropil et al., 2015) showed two distinct spatial patterns in the same local population (residential and migratory), and residential annual home ranges were significantly smaller compared to migratory ones, but residents expanded their space use in winter compared to other seasons. In their research, the longest movements were determined in three young stags emigrating to neighbouring mountain ranges (30, 47 and 65 km), and they concluded that the smallest area for unified management should be at least 300 km^2.

Elk (*Cervus elaphus*) dispersion from the release site depends on the impacts of many factors such as the length of time they were held prior to release, large predators, prevailing winds, geographical features of the area, age of released individuals, road density, hydro-electric corridors and human disturbance (Rosatte et al., 2007; Ryckman et al., 2010; Yott et al., 2011). We believe that the released red deer in the Tara area dispersed further in 2020 due to the COVID-19 pandemic, when many families from Belgrade and other large cities came to this mountain during a period of strict lockdown (to their own or rented cottages), which was the cause of frequent human disturbance. Some authors suggest that areas dominated by a single cover type with little interspersion of other habitats should be avoided for elk reintroduction (Larkin et al., 2004). These authors recommended areas with high levels of open-forest edge (≈ 5 km/km^2), which will likely enhance release-site fidelity and promote reintroduction success.

Wolf and brown bear predation, especially poaching and illegal shooting could be an important factor affecting red deer recruitment and reintroduction success, similar to the situation in some other countries (Rosatte et al., 2007; Yott et al., 2011), while further study in the area of Mt. Tara is required. Our results obtained in the period 2019-2021 provided only a partial insight into the directions and distances of movement after the release of red deer, which are probably much larger than shown by the collected records and GPS points (Fig. 4). For example, unverified data indicate that one group of released red deer crossed the state border between Serbia and B&H, and that it is located near the town of Višegrad.

The proposed reintroduction program for red deer in the Tara area contains the necessary elements and measures (Gačić et al., 2018), but many of them were modified during implementation, while some were not implemented. The main goal of this reintroduction was to form a self-sustaining and vital population of red deer in the selected favourable area (150 km^2) within a 20-year period. The population should reach an estimated capacity of 120 individuals, and serve for new settlements and sustainable use through hunting tourism.

Some authors (Yott et al., 2011) argue that the degree of movement and dispersal of animals from a temporary acclimatization enclosure (soft release), or from a release site (hard release) has the highest impact on the success of reintroduction. In addition, the key goal of reintroduction should be to increase the size of the population as soon as possible (Ryckman et al., 2010).

Our analysis showed that the established acclimatisation enclosure (3.63 ha) had a significantly smaller area than planned (7.29 ha), so that very favourable parts of the forest and three natural streams were left out. Moreover, the disinfection barrier at the main gate was not built, while the fence around the acclimatization enclosure was much weaker than designed, e.g. there was no electric fence on the outside for protection against large predators (wolves and brown bears), and no barbed wire above the upper part of the wire mesh with flags in the middle of the space between the poles, etc.

CONCLUSIONS
ZAKLJUČCI

The modern approach and methodologies used in this project ("SRBREDDEER") were appropriate and can be applied in other projects trying to reintroduce red deer to areas that were once part of its natural range, both in central Serbia and neighboring countries (B&H, Montenegro and North Macedonia). In the period 2019-2021, 74 red deers were released from the acclimatization enclosure in the Tara area, which is about 60% of the estimated capacity of the selected favourable area (150 km^2). Total mortality among the 72 red deer that were transported to the acclimatisation enclosure was 8.3%. During the study period, no bark stripping was observed outside the acclimatization enclosure, nor were any deaths of the released red deer registered. A large

number of the released red deer were moving within a 10 km-distance from the acclimatization enclosure.

Some of the most important problems in the implementation of the red deer reintroduction program in the Tara area are: 1) inadequate supervision regarding the realization of the established deadlines and implementation of elements of the program; 2) poorly organized monitoring of released red deer and its habitats; 3) lack of education of hunters and the local population; 4) lack of a plan for the management of red deer populations and hunting grounds at the regional and national level (e.g. Action Plan); and 5) potential conflicts between red deer and humans.

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ZAHVALA

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SAŽETAK

Suvremeni pristup u izradi programa za reintrodukciju jelena običnog bio je primijenjen po prvi put u Srbiji. U radu je dan prikaz planiranih i primijenjenih aktivnosti obnove populacije jelena običnog na lokalitetu Tara tijekom razdoblja 2018.-2021., kao i procjena ostvarena na području Tara. Plan je bio da se jelen obični (5♂ + 15♀) drži u prihvatilištu nekoliko mjeseci, a nakon toga ispusti u odabrano povoljno područje (150 km^2) tijekom tri uzastopne godine. Jelen obični je uglavnom gulio koru tanjih stabala obične lijeske (≤ 9.9 cm). Tijekom razdoblja transporta i boravka u prihvatilištu, od 72 jedinke jelena običnog uginulo ih je 6 (8.3%). Nakon ispuštanja iz prihvatilišta, četiri godine stara košuta (držana 15 sedmica u prihvatilištu) imala je najdulje pravocrtno kretanje od 24 km. Tijekom proučavanog razdoblja, izvan prihvatilišta nije evidentirano guljenje kore, niti su evidentirana uginuća ispuštenih jedinki jelena običnog. U razoblju 2019.-2021., 74 jedinke su ispuštene iz prihvatilišta u područje planine Tara, što iznosi oko 60% od procijenjenog kapaciteta odabranog povoljnog područja.

EJA STRNJARICA (*Circus cyaneus* L.)

Dr. sc. Krunoslav Arač, dipl. inž. šum.

Opisane su dvije podvrste, od kojih nominalnu susrećemo na području Europe i Azije, a *C.c. hudsonius* na području Sjeverne Amerike. Najrasprostranjenija je eja u Europi. Naraste u dužinu 41–55 cm s rasponom krila od 97 do 122 cm i težinom 290–600 (700) grama, pa ju po veličini možemo usporediti s ejom močvaricom ili škanjcem od kojih je neznatno manja. Mužjak i ženka eje strnjarice međusobno se razlikuju. Po veličini mužjaci su manji od ženki. Mužjak je svjetlo plavkasto sivi, osim crnih vrhova krila, izražene bijele trtice i bjelkastih donjih dijelova tijela. Ženka je tamnosmeđa s izraženo ispruganim repom, bijelom trticom, tamnijim licem i grlom na kojem je naglašena karakteristična crnkasta ogrlica. Krila su duga, rep je dug i uzak, a noge su izrazito žute boje. Tipična je ptica ravničarskih predjela vezana za otvorena prostrana poljoprivredna područja sa žitaricama i livadama, te staništa stepa, cretova, vriština i močvara. Tijekom zime susrećemo je i na oranicama i obalnim dinama. U Europi gnijezdi u središnjem dijelu, od Španjolske i Irske prema istoku. Gnijezda gradi na tlu u okružena gustom vegetacijom. Gnijezdi jednom tijekom godine od travnja do kolovoza. Gnijezdo je oskudno građeno od granja i suhih zeljastih stabljika. Nese 4–5 (3–8) jaja veličine 36x47 mm koja su plavkasto bijela s rijetkim sivo smeđim pjegama. Na jajima sjedi ženka (rijetko i mužjak) oko četiri tjedana. Mlade ptiće u gnijezdu hrane oba roditelja pet do šest tjedana, te nakon napuštanja gnijezda ostaju s roditeljima još dva do tri tjedna. Hrane se pretežno manjim sisavcima (pretežito glodavcima) i manjim pticama te, gmazovima, žabama i beskralješnjacima. Najčešće lovi iznad otvorenih površina obrušavanjem iz laganog niskog leta. U Hrvatskoj boravi od rujna do travnja kao redovita preletnica i zimovalica. Za vrijeme selidbe kao redovitu preletnicu možemo je opaziti na cijelom području tijekom rujna i listopada, te u travnju, a kao zimovalicu najčešće je opažamo u razdoblju od prosinca do veljače. Od svih europskih eja seli se na najkraće udaljenosti u širokom pojasu prema jugu i jugozapadu, pojedinačno ili u manjim jatima, pa većina populacije zimuje uglavnom na području Europe.

Eja strnjarica je zaštićena vrsta u Republici Hrvatskoj, a u Crvenoj knjizi ptica Hrvatske nalazi se na popisu najmanje zabrinjavajućih vrsta (LC).

Mužjak je svjetlo plavkasto sive boje, po nekim autorima je najljepša ptica iz reda sokolovki u Europi

Ženka u lovu u laganom niskom letu s vidljivom karakterističnom tamnom ogrlicom na grlu

TECHNODIVERSITY: HARMONISING EUROPEAN EDUCATION IN FOREST ENGINEERING BY IMPLEMENTING AN E-LEARNING PLATFORM TO SUPPORT ADAPTATION AND EVALUATION OF FOREST OPERATIONS

Doc dr. sc. Andreja Đuka

Co-funded by the Erasmus+ Programme of the European Union

Faculty of Forestry and Wood Technology University of Zagreb is included in an Erasmus+ programme Action Type KA220-HED – Cooperation partnerships in higher education together with seven other European institutions:

- Dresden University of Technology, Germany (leader), prof. Jöern Erler, PhD, Christina Spirrow, M.A. and Clara Bade, BSc
- Poznań University of Life Sciences, Poland, prof. Piotr S. Mederski, PhD
- National Research Council, Italy, Raffaele Spinelli, PhD and Marco Simonetti, MSc
- Transilvania University of Brașov, Romania, prof. Stelian A. Borz, PhD
- University of Natural Resources and Life Sciences, Austria, prof. Karl Stampfer, PhD
- Swedish University of Agricultural Sciences, Sweden, prof. Ola Lindroos, PhD and Mikael Lundbäck, PhD
- Faculty of Forestry and Wood Technology University of Zagreb, Croatia, assist. prof. Andreja Đuka, PhD
- Technological Institute FCBA, France, Nathalie Mionetto, PhD and Philippe Ruch, forest research engineer

The Technodiversity project addresses technological diversity by summarising technological knowledge and increasing the sensitivity for diversity in forest engineering. The goal of the project is to connect and show the existing knowledge in forest operations of various European countries. It will function as a span between different regions of Europe as well as between different generations of students, practitioners, scientists and academics. An e-learning course will be installed to support mobility for students on master's level of education, suitable for implementation into forestry-based curricula. The course will be recognized by forest faculties in Europe and integrated with 10 ECTS in the forest master curriculum. In addition, it could also be used as a further training unit for forestry practitioners.

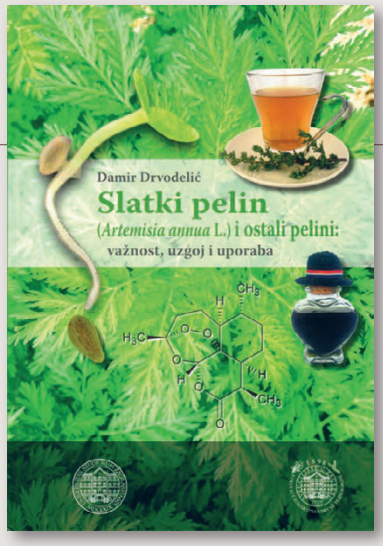
Lectures and a glossary with facts and methods will be the knowledge base, where the most typical technological subprocesses for wood harvesting will be presented and assessed. Tutorials will explain how to structure and express different technological processes under ecological, economic, and societal criteria under each specific condition. For each sub process a scientific audio-visual will show the tool or machine/vehicle, its use and the effects on the environment and the workers, its expected productivity and the resulting costs. A platform will ensure organisation and

Fig. 1 Harvesting operations in Italy

Fig. 2 Harvesting operations in Croatia and Sweden

coordination of complex information. In an intuitive, modular way, users will be able to identify those sub-processes that fit their local conditions, and combine them into a complete work process. User will get suitable information to assess the selected process and to find the optimal solutions for their individual needs and objectives.

ERRATA CORRIGE



U dvobroju Šumarskoga lista 7-8 2022. u rubrici KNJGE I ČASOPISI prikana je knjiga Izv. prof. dr. sc. Damira Drvodelića Slatki pelin (*Artemisia annua* L.) i ostali pelini: važnost, uzgoj i uporaba. Tehničkom greškom izostavljena je uobičajeno ilustrirana naslovnica knjige. Zbog korektnosi i uz isprike autoru objavljujemo je u ovom dvobroju.

KORISNE BILJKE

Ivana Visović Kosić, Branko Bakan, Gregor Fištravec, Mitja Garić

PRIRUČNIK ZA PREPOZNAVANJE SAMONIKLIH BILJAKA S NAGLASOM NA NJIHOVU KORISNOST

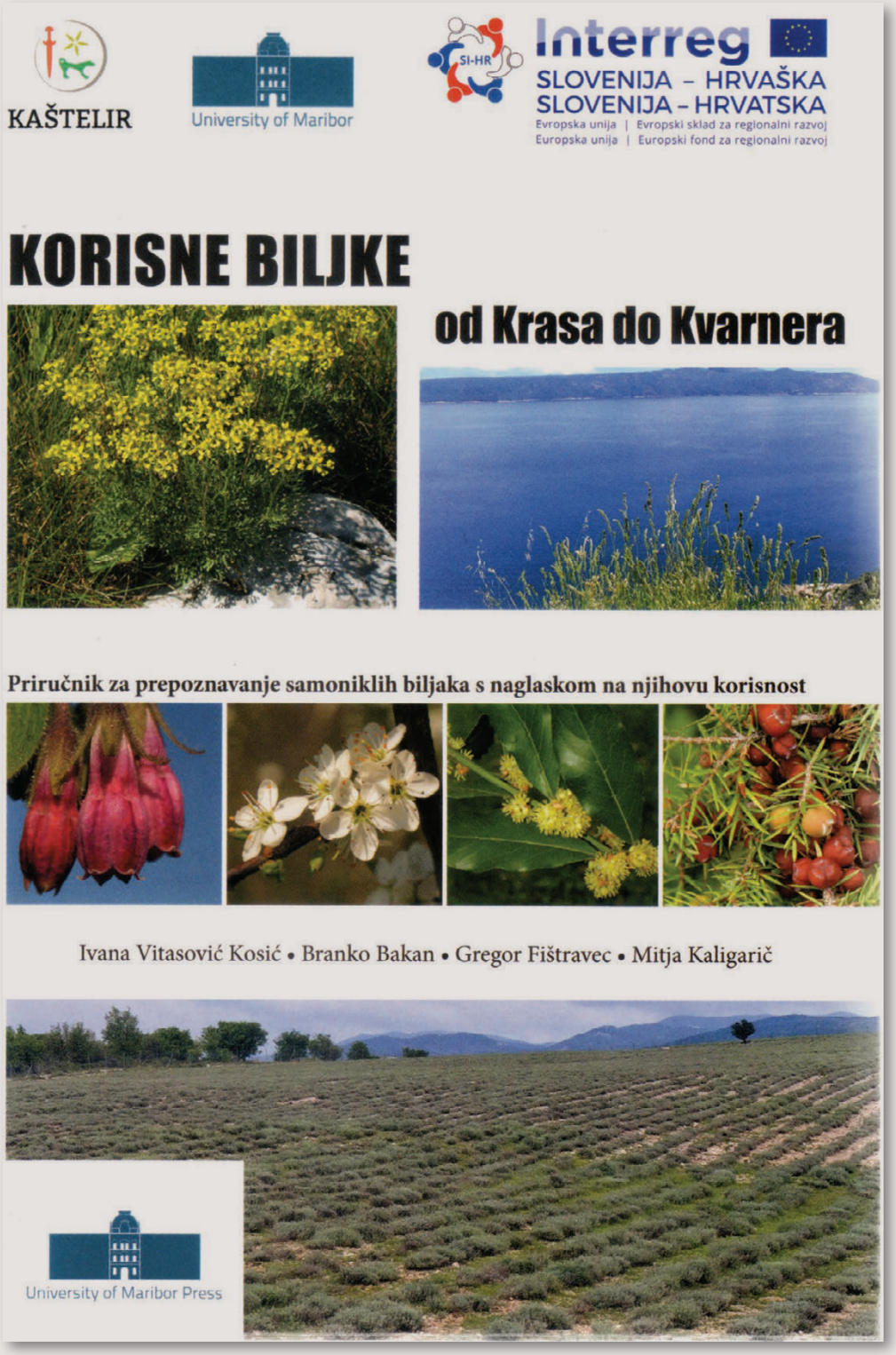
Prof. dr. sc. Milan Glavaš

Knjiga je tiskana u Mariboru 2021. godine. Prva autorica je docentica na Agronomskom fakultetu u Zagrebu, a ostali su iz Slovenije. Knjiga je obima preko 300 stranica. Nastala je kao rezultat dugogodišnjeg istraživanja istarskog i šireg područja. Uz svaku biljku priložene su oznake za lakše snalaženje (boja cvijeta, podjela biljaka prema obliku simetrije i cvijeta, način uporabe biljaka, dijelovi biljaka koji su prikladni za uporabu, oznaka ugroženosti biljke, vrijeme branja pojedinih dijelova biljke, upozorenje o štetnim učincima, potencijalno otrovna ili slabo alergena biljka, vrlo otrovna ili vrlo alergena biljka).

Na početku knjige ukazuje se na vezu biljaka i prapovijesti. Navodi se kako je čovjek u pradavna vremena prepoznavao i koristio biljke. Ističu da se flora na području između Krasa i Kvarnera nije značajno promijenila. Zato su u ovoj knjizi predstavljene korisne samonikle biljke (uz nekoliko izuzetaka kultiviranih biljaka) na tom području. Slijedi predstavljanje oblika i tipova vegetacije Krasa, Istre i Kvarnera. Ukazuje se na pet šumskih pojasa. Vrlo korisne upute navedene su o livadama i pašnjacima u prošlosti i sada. Ističu da su oni korisniji od šuma. Oni u južnoj Istri pripadaju eumediteranskom razredu travnjačke vegetacije. Na istraživanom području su češći submediteranski kamenjarski pašnjaci i suhi travnjaci. Zatim navode koje vrste karakteriziraju travnjake na flišu, vapnencima i kamenitom tlu i koje ih vrste karakteriziraju te o čemu ovisi njihov floristički sastav. Naveli su koje vrste karakteriziraju travnjake, tumači se značenje livada. Na krškom platou razvijaju se pašnjaci i livade. Ako se livade ne kose, ugrožene su zbog zarastanja, zbog toga preporučuju košnju. Na istraživanom području najčešći oblik su pašnjaci koji obuhvaćaju nešumske predjele vapnenačkih naslaga. Na tom području ispaše gotovo ni nema, a košnja je ograničena i rijetka. To je dovelo do masovnih obrastanja ovoga područja. Na nekim mjestima travnjaci se floristički već sastoje od nekih šumskih biljaka. Navode koja je zajednica najrasprostranjenija i njene uobičajene vrste. Neke vrste ovih travnjaka rastu samo na Ćićariji, navedeno je koje su to vrste. Tekst završava navodom da su travnjaci slovenskog Krasa i Istre vrlo raznoliki vrstama, s posebno visokim udjelom aromatičnih i začinskih biljaka. Dalje se govori o kodeksu sakupljanja

biljaka, pogotovo začinskih. Ukazuju da pri sakupljanju treba poštivati pravila i smjernice za ponašanje u prirodi, o čemu navode opće odredbe. Posebno se ukazuje na odredbe za sakupljanje biljaka za hranu, začine i lijekove i na što treba obratiti pozornost prilikom sakupljanja. Na kraju se daju detaljne upute kako koristiti priručnik. Navodi se da su opisane biljke grupirane prema boji cvjetova (5 grupa). Opisane su karakteristike cvjetova. Slijede upute o opisanim biljkama.

Za svaku biljku na lijevoj stranici prikazana je fotografija. U dnu je naveden znanstveni naziv i hrvatski i slovenski naziv biljke. Na desnoj stranici, uz lijevi rub nalaze se 2 ili 3 male fotografije s navodima karakteristika za dotičnu vrstu. Uz to slijedi tekst o biljci. Prvo je navedeno kojoj porodici biljka pripada, zatim je dan opis kako biljka izgleda pa stanište i rasprostranjenost. Navedeno je vrijeme sakupljanja pojedinih dijelova. Posebno su navedeni podatci o uporabi i aktivnim sastojcima biljke, odnosno njenih dije-



lova. Tu je navedena njena uporaba, prehrambene i ljekovite svrhe, uzgoj kao ukrasne biljke, a kod drvenastih vrsta i uporaba drveta. Na dnu je crvenim slovima napisano upozorenje o štetnosti i otrovnosti dotične vrste. S desne strane, na rubu stranice, dane su grafičke oznake važne za karakteristike biljke.

Prema analizi opisanih biljaka daje se sljedeći prikaz:

– Po boji cvjetova biljke su grupirane u 5 skupina; biljke bijelih cvjetova (42), biljke žutih ili narančastih cvjetova (34), biljke crvenih, ružičastih ili purpurnih cvjetova (25), biljke plavih ili ljubičastih cvjetova (18) i biljke zelenih ili smeđih cvjetova (33).

Po sistematskoj pripadnosti biljke su svrstane u 61 porodicu i 130 rodova. Po brojnosti najopsežnije su porodice *Rosaceae* – ružatice (12 rodova i 18 vrsta), *Lamiaceae* – usnače (15 rodova i 15 vrsta) i *Asteraceae* – glavočike cjevnjače (15 rodova i 15 vrsta). Važno je istaći da među opisanim biljkama naznačeno preko 100 ljekovitih (iako ih ima oko 130) i 98 jestivih vrsta.

Na kraju knjige dan je popis korištene literature (56 izvora) i kazalo hrvatskih, znanstvenih i lokalnih naziva opisanih biljaka.

Zaključak

Iz opisa biljaka vidljivo je da su većinom vezane za šume, pa je stoga priručnik koristan šumarima. Podaci o biljkama napisani su jasno i vrlo precizno. Priručnik je primjenjiv i izvan opisanog područja. Upute u priručniku mogu biti korisne biolozima, amaterima i stručnjacima za stvaranje vlastitih zbirki ljekovitog, začinskog, jestivog i ukrasnog bilja te svima zainteresiranima za prirodu i koristi od istog.

PRIZNANJE VADAS JENŐ

Dr.sc. Tibor Littvay

Na svečanoj sjednici povodom 152. godišnje skupštine Mađarskog šumarskog društva, (osnovanog 1866. godine) održanoj u četvrtak 30. lipnja 2022. u mjestu Gödöllö, u Kraljevskom dvorcu u blizini Budimpešte, održana je svečana dodjela priznanja kolegicama i kolegama šumarima u raznim područjima svoga djelovanja. Godišnja skupština i svečana dodjela priznanja održane su pod pokroviteljstvom ustanove Park-šume Pilisi (Piliši) i Ministarstva poljoprivrede. Skupštini je nazočilo oko 500 šumara iz Panonske regije. Svečanu sjednicu otvorio je **Kiss László,** predsjednik Mađarskog šumarskog društva (Országos Erdészeti Egyesület). Skup je pozdravio i zamjenik predsjednika Mađarske **Zsolt Semjén,** koji je naglasio važnost šumarske struke u novonastalim prilikama klimatskih promjena. Skup je pozdravio i **István Nagy,** ministar poljoprivrede Mađarske, koji je s ponosom govorio o šumarskoj struci kao jednoj od, za budućnost vrlo važnih segmenata ljudske djelatnosti.

Na godišnjoj skupštini znanstvenik Hrvatskog šumarskog instituta u mirovini dr. sc. Tibor Littvay primio je spomen medalju Vadas Jenö (1857-1922) za dugogodišnju, preko dva desetljeća, suradnju i znanstveno istraživanje s kolegama iz Mađarske. Vadas Jenö je 1901. godine bio je direktor IUFR-a (Svjetske znanstvene šumarske organizacije) i vrlo priznati šumarski stručnjak u mađarskoj i inozemstvu.

Prijevod obrazloženja dodjele spomen medalje Vadas Jenő

Stručno djelovanje Vadasa Jenő i njegovo cjeloživotno duhovno vodstvo u šumarstvu, učinili su ga

dostojnim da se spomen medalja s njegovim imenom dodjeljuje stručnjacima koji su dali veliki doprinos šumarskoj znanstvenoj djelatnosti, provedbi rezultata istraživanja u praksi, kao i njihovu priznanju.

U ime uprave Šumarskog znanstvenog instituta Sveučilišta Sopron, (Šopron) izražavamo svoju

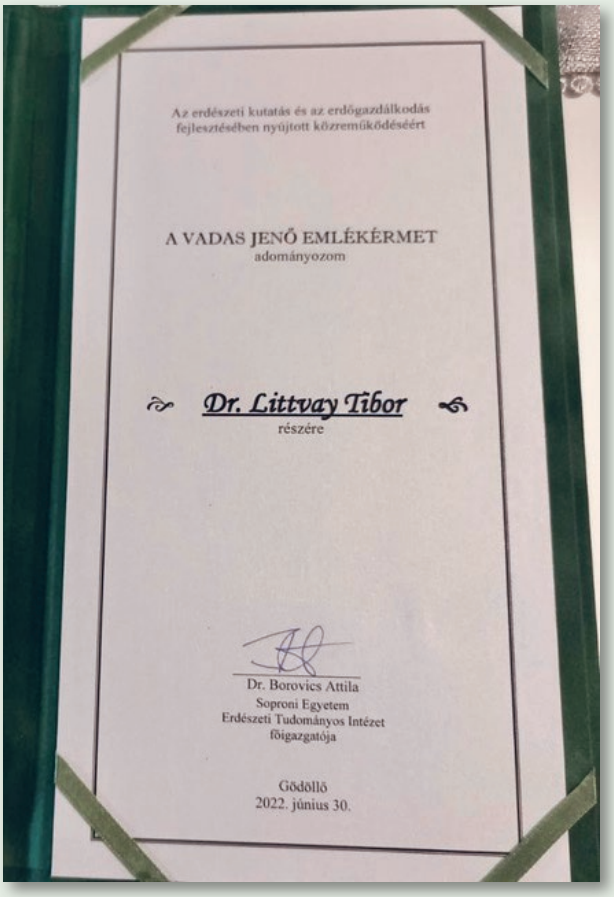
zahvalnost i poštovanje dr. sc Tiboru Littvayu povodom dodjele Spomen medalje Vadas Jenő za 2022. godinu.

Priznanje je uručio dr. sc. Borovics Attila direktor Šumarskog znanstvenog instituta, Sveučilišta Sopron (Šopron)

Amblem Mađarskog Šumarskog društva

Amblem ovogodišnjeg sastanka i strukovnog pokrovitelja Piliši-park šume pod motom park šume za čovjeka

SPOMEN MEDALJA



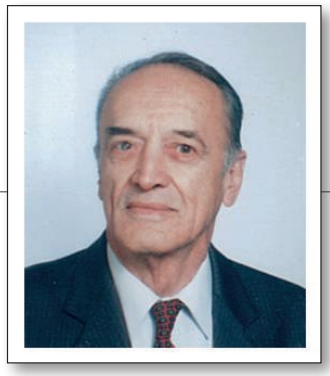
PRIZNAJE

Otvaranje svečane sjednice

Dr. sc. Tibor Littvay sa suprugom i dr. sc. Attila Borovics

Mr. sc. Andrija Vranković (24.11.1930.-04.7.2022.)

Prof. dr. sc. Nikola Pernar



Dana 4. srpnja 2022. u 92. godini života zauvijek nas je napustio naš uvaženi kolega i prijatelj, dugogodišnji nastavnik Fakulteta šumarstva i drvne tehnologije, mr. sc. Andrija Vranković. Oprostili smo se od njega na Mirogoju 7. srpnja 2022. g. Završio je sadržajan i bogat život, obilježen dobrotom i osebujnošću, vrline po kojima ćemo se Andrije uvijek sjećati. Napustio nas je znanstvenik, nastavnik, gospodin i veliki čovjek Andrija Vranković.

Andrija (za prijatelje i obitelj Jandro) rođen je 24. studenoga 1930. godine od majke Stoše i oca Bože u Rtini, jugoistočno od Paškog mosta. Osnovnu školu završio je na otoku Pagu, gimnaziju u Makarskoj, a Srednju šumarsku školu za krš u Splitu. Nakon trogodišnjeg službovanja u šumarijama Zadar, Šibenik i Benkovac upisao se 1954. na Poljoprivredno-šumarski fakultet u Zagrebu, a po završetku studija Šumarstva, 1960. u zvanju asistenta susreće se s pedologijom (znanošću o tlu) koja je odredila koordinate njegovoga života, posebice u smislu stručnog i znanstvenog formiranja. Te godine izabran je za asistenta u zajedničkom Zavodu za pedologiju Poljoprivrednog i Šumarskog fakulteta i upisao je poslijediplomski studij iz Pedologije. U želji da afirmira šumarsku pedologiju kao samostalnu šumarsku disciplinu i da je poveže s ostalim graničnim znanostima, studira na Prirodoslovno-matematičkom fakultetu u Zagrebu, na Geološko-paleontološkom odjelu, predmete Geologiju, Petrografiju, Mineralogiju i Paleontologiju. Tako je akademske godine 1963/64. predavao studentima šumarstva predmet Petrografija s geologijom i posebno se angažirao na dogradnji petrološke zbirke i zbirke monolita šumskih tala.

Magistrirao je 1973. godine s temom "Tla na kalcitnim i nekim silikatnim metamorfitima metamorfnog facijesa zelenog škriljavca na Zagrebačkoj gori i Papuku". Iste godine boravio je na specijalizaciji na Biološko-pedološkom fakultetu u Moskvi. Nakon magistriranja izabran je u zvanje predavača i tako postao prvi šumar kao sveučilišni nastavnik iz pedologije na Sveučilištu u Zagrebu.

Od uspostave Katedre za pedologiju na Šumarskom fakultetu, 1973. god., sve do umirovljenja krajem 1995., predavao je Pedologiju i srodne predmete na dodiplomskom i poslijediplomskim studijima. Kroz to vrijeme obnašao je dužnost predstojnika Katedre za pedologiju, a od 1972. do 1992., bio je i upravitelj Nastavno-pokusnog šumskog objekta "Velika".

Bio je član Međunarodnog pedološkog društva, Društva za proučavanje tla Hrvatske (današnjeg HTD-a, kojim je predsjedao od 1986. do 1988.), Hrvatskog ekološkog društva, Hrvatskog šumarskog društva te radnih grupa vezanih za motrenje i zaštitu tla.

Mr. sc. Andrija Vranković objavio je samostalno i u suradnji sedamdesetak znanstvenih radova i pedoloških karata. Sudjelovao je u zemlji i inozemstvu na više znanstvenih i stručnih skupova, a bio je na studijskim boravcima u Čehoslovačkoj, Ukrajini, Nizozemskoj, Gruziji i Armeniji.

Znanstvenoistraživački rad mr. sc. A. Vrankovića obuhvaća više tematskih područja unutar tloznanstva - to su: kartiranje, geneza i klasifikacija tala, erozija, zaštita i štetni kemizam tla, ekološka valorizacija i plodnost tla radi podizanja šumskih kultura i rasadnika, promjene vodno-zračnog režima u hidromorfnim tlima, odnos između svojstava tla i šumske mehanizacije te onečišćenje tla aeropolucijom. Većina njegovih radova odnose se na tlo krša, od Istre do srednje Dalmacije. Uz autorske pedološke karte i tumača, to su monografije i radovi objavljeni u časopisima ili prezentirani na skupovima. Tijekom 70-ih i 80-ih godina sudjelovao je u kapitalnom projektu inventarizacije tala Hrvatske, na projektima istraživanja sušenja hrasta, sušenja bukve, oštećenja tla u šumarstvu i u naseljima i na nizu drugih znanstvenih i stručnih projekata, što je rezultiralo njegovim najvažnijim znanstvenim i stručnim radovima.

Raspon tloznanstvenih tema kojima se bavio mr. sc. Andrija Vranković može se ilustrirati s nekoliko naslova radova koje je objavio samostalno ili u suautorstvu:

Pedološki prikaz tala nekih šumsko-gospodarskih jedinica u planinskom masivu Mala Kapela.

Ekološko-uzgojne osobine specijalnih rezervata šumske vegetacije Prašnik i Muški bunar.

Oštećenje šumskih tala ledoizvalama na nekim metamorfitima Kalnika.

Subakvalna tla Plitvičkih jezera.

Neke pedološke karakteristike fitoklimatskih područja Velebita.

Klasifikacija pogodnosti tala za višestruku funkciju šume.

Prilog poznavanju ekoloških odnosa u zagrebačkom gradskom raslinstvu.

Oštećenja šumskog tla izvlačenjem drva i njegova regeneracija.

Vrijednosti kritičnih opterećenja šumskog ekosustava sumporom i dušikom na području zapadne Hrvatske.

Promjena stanja humizacije u **šumi** bukve i jele na kršu zapadne Hrvatske.

Kao član Komisije UNESCO-a 1965. sudjelovao je na uspostavi sustava determinacije i korelacije tala za područje Balkana. Početkom 70-ih, sudjelovao je na izradi projektne dokumentacije za hidrološko i vegetacijsko uređenje područja Bir Ayyad u Libiji, a 1985. na projektu ekološkog uređenja brane Zeralda u Alžiru.

Bio je sudionik NOR-a od 1944. i Hrvatskog proljeća 1971. Odlikovan je Ordenom zasluga za narod sa srebrnim zracima, u povodu 40. godišnjice oslobođenja grada Poveljom Sveučilišta, a za uspješan rad na izradi Osnovne pedološke karte Diplomom RZ za znanstveni rad Republike Hrvatske.

Redajući ovdje činjenice o mr. sc. A. Vrankoviću važno je ne izostaviti i ono bitno, što nije zapisano u danas lako dostupnim izvorima; krasila ga je nesebičnost, jednostavnost, kolegijalnost i susretljivost prema suradnicima i studentima. Bio je izuzetan i kao suprug, otac i djed, kao kolega i prijatelj.

Nakon umirovljenja rado je viđen kao suradnik Fakulteta, a u poznijim godinama kao dragi gost, posebno na prigodnim zavodskim i fakultetskim druženjima.

Odlaskom mr. sc. Andrije Vrankovića osjeća se nenadoknadiv gubitak i praznina, ali ostaje i trag jednog bogatog života, utisnutog u sjećanja svih koji su ga poznavali. Ostaje trag vrijedan poštovanja i zahvalnosti; jednostavno, ostaje lijepo sjećanje na Andriju Vrankovića.

Dragi naš profesore, dragi naš Jandro, neka Ti je vječna slava.

Poštarina paušalirana.

ŠUMARSKI LIST

Izdaje Jugoslovensko Šumarsko Udruženje

Uređuje redakcioni odbor. — Glavni i odgovorni urednik: ing. Milan Marinović.
Uredništvo i uprava nalazi se u Zagrebu, Šumarski dom.

Izlazi jedanput mjesečno. — Članovi Udruženja dobivaju ga besplatno. — Za nečlanove pretplata 50 Din.

Br. 9. Zagreb, 1. septembra 1922. God. 46.

Sadržaj:

UPUTE AUTORIMA

Šumarski list objavljuje znanstvene i stručne članke iz područja šumarstva, odnosno svih znanstvenih grana pripadajućih šumarstvu, zatim zaštite prirode i lovstva. Svaki znanstveni i stručni članak trebao bi težiti provedbi autorove zamisli u stručnu praksu, budući da je šumarska znanost primjenjiva. U rubrikama časopisa donose se napisi o zaštiti prirode povezane uz šume, o obljetnicama, znanstvenim i stručnim skupovima, knjigama i časopisima, o zbivanjima u Hrvatskom šumarskom društvu, tijeku i zaključcima sjednica Upravnoga odbora te godišnje i izvanredne skupštine, obavijesti o ograncima Društva i dr.

Svi napisi koji se dostavljaju Uredništvu, zbog objavljivanja moraju biti napisani na hrvatskom jeziku, a znanstveni i stručni radovi na hrvatskom ili engleskom jeziku, s naslovom i podnaslovima prevedenim na engleski, odnosno hrvatski jezik.

Dokument treba pripremiti u formatu A4, sa svim marginama 2,5 cm i razmakom redova 1,5. Font treba biti Times New Roman veličine 12 (bilješke – fusnote 10), sam tekst normalno, naslovi bold i velikim slovima, podnaslovi bold i malim slovima, autori bold i malim slovima bez titula, a u fusnoti s titulama, adresom i elekroničkom adresom (E-mail). Stranice treba obrojčati.

Opseg teksta članaka može imati najviše 15 stranica zajedno s prilozima, odnosno tablicama, grafikonima, slikama (crteži i fotografije) i kartama. Više od 15 stranica može se prihvatiti uz odobrenje urednika i recenzenata. Crteže, fotografije i karte treba priložiti u visokoj rezoluciji.

Priloge opisati dvojezično (naslove priloga, glave tablica, mjerne jedinice, nazive osi grafikona, slika, karata, fotografija, legende i dr.) u fontu Times New Roman 10 (po potrebi 8). Drugi jezik je u kurzivu. U tekstu označiti mjesta gdje se priložio moraju postaviti.

Rukopisi znanstvenih i stručnih radova, koji se prema prethodnim uputama dostavljaju uredništvu Šumarskoga lista, moraju sadržavati sažetak na engleskom jeziku (na hrvatskome za članke pisane na engleskom jeziku), iz kojega se može dobro indeksirati i abstraktirati rad. Taj sažetak mora sadržavati sve za članak značajno: dio uvoda, opis objekta istraživanja, metodu rada, rezultate istraživanja, bitno iz rasprave i zaključke. Sadržaj sažetka (Summary) mora upućivati na dvojezične priloge – tablice, grafikone, slike (crteže i fotografije) iz teksta članka.

Pravila za citiranje literarture:

Članak iz časopisa: Prezime, I., I. Prezime, 2005: Naslov članka, Kratko ime časopisa, Vol. (Broj): str.–str., Grad

Članak iz zbornika skupa: Prezime, I., I. Prezime, I. Prezime, 2005: Naslov članka, U: I. Prezime (ur.), Naziv skupa, Izdavač, str.–str., Grad

Članak iz knjige: Prezime, I., 2005: Naslov članka ili poglavlja, Naslov knjige, Izdavač, str.–str., Grad

Knjiga: Prezime, I., 2005: Naslov knjige, Izdavač, xxxx str., Grad

Disertacije i magistarski radovi: Prezime, I., 2003: Naslov, Disertacija (Magisterij), Šumarski fakultet Zagreb. (I. = prvo slovo imena; str. = stranica)

INSTRUCTIONS FOR AUTHORS

Forestry Journal publishes scientific and specialist articles from the fields of forestry, forestry-related scientific branches, nature protection and wildlife management. Every scientific and specialist article should strive to convert the author's ideas into forestry practice. Different sections of the journal publish articles dealing with a broad scope of topics, such as forest nature protection, anniversaries, scientific and professional gatherings, books and magazines, activities of the Croatian Forestry Association, meetings and conclusions of the Managing Board, annual and extraordinary meetings, announcements on the branches of the Association, etc.

All articles submitted to the Editorial Board for publication must be written in Croatian, and scientific and specialist articles must be written in Croatian and English. Titles and subheadings must be translated into English or Croatian.

Documents must be prepared in standard A4 format, all margins should be 2.5 cm, and spacing should be 1,5. The font should be 12-point Times New Roman (notes – footnotes 10). The text itself should be in normal type, the titles in bold and capital letters, the subheadings in bold and small letters, and the authors in bold and small letters without titles. Footnotes should contain the name of the author together with titles, address and electronic address (e-mail). The pages must be numbered.

A manuscript with all its components, including tables, graphs, figures (drawings and photographs) and maps, should not exceed 15 pages. Manuscripts exceeding 15 pages must be approved for publication by editors and reviewers. The attached drawings, photographs and maps should be in high resolution.

All paper components should be in two languages (titles of components, table headings, units of measure, graph axes, figures, maps, photographs, legends and others) and the font should be 10-point Times New Roman (8-point size if necessary). The second language must be in italics. Places in the text where the components should be entered must be marked.

Manuscripts of scientific and specialist papers, written according to the above instructions and submitted to the Editorial Board of Forestry Journal, must contain an abstract in English (or in Croatian if the article is written in English). The abstract should allow easy indexation and abstraction and must contain all the key parts of the article: a part of the introduction, description of research topic, method of work, research results, and the essentials from the discussion and conclusions. The summary must give an indication of bilingual components – tables, graphs and figures (drawings and photographs) from the article.

Rules for reference lists:

Journal article: Last name, F., F. Last name, 2005: Title of the article, Journal abbreviated title, Volume number: p.–p., City of publication

Conference proceedings: Last name, F., F. Last name, 2005: Title of the article, In: M. Davies (ed), Title of the conference, Publisher, p.–p., City of publication

Book article: Last name, F, 2005: Title of the article or chapter, Title of the book, Publisher, p.–p. City of publication

Book: Last name, F, 2005: Title of the book, Publisher, xxxx p., City of publication

Dissertations and master's theses: Last name, F., 2003: Title, Dissertation (Master's thesis), Faculty of Forestry, Zagreb) (F. = Initial of the first name; p. = page)

Slika 1. Baldžuanski dvornik na Braču. ■ **Figure 1.** Silver lace vine on the island of Brač (Croatia).

Slika 3. Cvjetovi su 6–8 mm promjera; cvjetanje je od lipnja do listopada. ■ **Figure 3.** Flowers are 6–8 mm in diameter, produced from June to October.

Slika 2. Listovi su 4–10 cm dugački, 3–5 cm široki; peteljka je 1–3,5 cm dugačka. ■ **Figure 2.** Leaves are 4–10 cm long, 3–5 cm wide; petiole is 1–3.5 cm long.

Slika 4. Plodovi su anemohorni, ovijeni bijelim (ili katkada ružičastim), kasnije smeđim, trokrilnim perigonom. ■ **Figure 4.** Fruits are anemochorous, enclosed by persistent perigon; perigon is white, sometimes pinkish, becoming brown, 3-winged.

Fallopia baldschuanica (Regel) Holub – baldžuanski dvornik (*Polygonaceae*)

Fallopia baldschuanica (*Polygonum baldschuanicum* Regel, *Reynoutria baldschuanica* (Regel) Moldenke) je listopadna, brzorastuća, 5–10 (–15) m visoka, azijska povijuša. Listovi su jednostavni, naizmjenični, jajasti, šiljastog do tupog vrha, srcaste do kopljaste osnove, cijelog i valovitog ruba. Cvjetovi su dvospolni, entomofilni, bijeli, sitni, u vršnim i postranim, rahlim, uspravnim do horizontalnim, velikim cvatovima. Plod je sitni, crni, sjajni oraščić. Baldžuanski dvornik je često uzgajana ukrasna povijuša na zidovima, ogradama ili pergolama, ali se može koristiti i kao pokrivač tla. Tolerira širok raspon edafskih i temperaturnih uvjeta i preferira položaj na izravnom svjetlu ili u polusjeni. Može se orezivati krajem zime ili početkom proljeća, prije listanja.

Fallopia baldschuanica (Regel) Holub – Silver Lace Vine (*Polygonaceae*)

Fallopia baldschuanica (*Polygonum baldschuanicum* Regel, *Reynoutria baldschuanica* (Regel) Moldenke) is a deciduous, fast-growing, twining, 5–10(–15) m tall climber native to Asia. Leaves are simple, alternate, ovate, with acuminate to obtuse apex, cordate to sagittate base and entire, wavy margin. Flowers are bisexual, entomophilous, white, small, borne in terminal and axillary, loose, erect to horizontal, large inflorescences. The fruit is a small, black, shiny nut. Silver lace vine is a widely cultivated climbing ornamental plant on walls, fences or pergolas, but can also be grown as a ground cover. It tolerates a wide range of temperature and soil conditions. It prefers full sun to partal shade and can be pruned in late winter to early spring, before new growth begins.

Tekst i fotografije: prof. dr. sc. Marilena Idžojtić