

Gozdarski inštitut Slovenije
Silva Slovenica

Studia Forestalia Slovenica
Strokovna in znanstvena dela

135

**TRAJNOSTNA RABA LESA V KONTEKSTU
SONARAVNEGA GOSPODARJENJA Z GOZDOVI**

***RATIONAL USE OF WOOD IN THE CONTEXT OF
SUSTAINABLE FOREST MANAGEMENT***

Uredila
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Ljubljana, 2009

UDK 88:611
GDK 630*88:630*6

ISSN = 0353-6025

Studia Forestalia Slovenica / *Strokovna in znanstvena dela* 135

Izdaja / *Issued by*
Gozdarski inštitut Slovenije, Založba: *Silva Slovenica*
Večna pot 2, SI-1000 Ljubljana, Slovenija
<http://www.gozdis.si>

Uredniški odbor serijske publikacije Studia forestalia Slovenica / *Editorial board of serial publication Studia forestalia Slovenica*
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Naslov / *Title*
Trajnostna raba lesa v kontekstu sonaravnega gospodarjenja z gozdovi
Rational use of wood in the context of sustainable forest management

Glavna in odgovorna urednika / *Editor in Chief*
doc. dr. Miha HUMAR, prof. dr. Hojka KRAIGHER

Računalniški prelom / *Text design*
Blaž BOGATAJ

Oblikovanje naslovnice / *Cover page design*
Miha HUMAR

Slike na naslovnici / *Photos on cover page*
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Dokumentacijska obdelava / *Indexing, classification and abstracting*
mag. Maja BOŽIČ, univ. dipl. bibl.

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

630*624(082)

TRAJNOSTNA raba lesa v kontekstu sonaravnega gospodarjenja z
gozdovi / [glavna urednika Miha Humar, Hojka Kraigher]. - Ljubljana
: Gozdarski inštitut Slovenije, Založba Silva Slovenica, 2009. –
(Studia forestalia Slovenica : strokovna in znanstvena dela ; 135)

ISBN 978-961-6425-45-2
1. Humar, Miha
246993408

Tisk / *Print*:
LITTERA PICTA d.o.o.
Število izvodov / *Number of issues*
300

Strokovna in znanstvena dela so referirana v mednarodnih bibliografskih zbirkah: CAB, Abstracts, TREECD, AGRIS
Abstracts from the journal are comprised in the following international bibliographic databases: CAB, Abstracts, TREECD, AGRIS

Sofinanciranje / *Co-financing*
Javna agencija za raziskovalno dejavnost Republike Slovenije / *Slovenian research agency*, Javna agencija za knjigo
Republike Slovenije / *Slovenian Book Agency*

Monografija obravnava najpomembnejše bogastvo, ki ga imamo v Sloveniji na voljo, gozd oziroma les. Monografija Trajnostna raba lesa v kontekstu sonaravnega gospodarjenja z gozdovi je nastala na podlagi raziskav usmerjenega aplikativnega projekta, ki ga je sofinancirala Agencija za raziskovalno dejavnost Republike Slovenije. Izbrani projekt je bil edini in prvi primer, ki združuje vsa tri različna področja raziskovalnega področja Gozdarstvo, lesarstvo, papirništvo. Tako monografija kot tudi projekt sta obravnavala les od zibelke do groba. Pri tej monografiji z 19 prispevki sodelujemo vse tri inštitucije nacionalnega pomena, ki pokrivajo to področje, in sicer: Biotehniška fakulteta, Gozdarski inštitut Slovenije in Inštitut za celulozo in papir.

Glavna tematika te monografije sta gozd in les. Zavedati se moramo, da gozdovi pokrivajo prek 60 % nacionalnega ozemlja Slovenije. Njihova površina se je od l. 1875 (737 000 ha) do danes povečala za približno 500 000 ha! Kljub dolgoletni tradiciji sonaravnega gospodarjenja z gozdom in rabe lesa pa posek močno zaostaja za prirastkom, kar se kaže tudi v hitrem staranju gozdov in padcu kakovosti lesa. Zato je pomembno čim bolj spodbuditi zdravo rabo lesa. Pomen gozda in lesa v zadnjem času močno narašča, saj je obdelava lesa energetsko nepotratna in okolju prijazna. Poleg tega vedno bolj prihaja v ospredje dejstvo, da so les in lesni izdelki pomembni tudi z vidika skladiščenja ogljika. Les namreč skozi celotno življenjsko dobo skladišči ogljikov dioksid.

V monografiji smo se osredotočili na več vidikov, ki so podrobneje predstavljeni v 19 znanstvenih poglavjih, ki pokrivajo celotno verigo od gozda do lesa oziroma papirja. Avtorji poglavij so priznani strokovnjaki / znanstveniki s področja gozdarstva, lesarstva in papirništva. Tako je ta monografija prvo znanstveno delo, ki v celoti in enakovredno pokriva ta tri med seboj povezana področja.

V uvodnih poglavjih smo se posvetili predvsem negospodarski funkciji gozda. Le-ta vedno bolj prihaja v ospredje. Sonaravno oskrbovan gozd je temelj za zanesljivo oskrbo z vodo in nenazadnje so gozdovi pljuča našega planeta. V nadaljevanju avtorji poudarjamo, da je gozd veliko več kot le to, kar vidimo na prvi pogled. Temelji gozda so osnova za zdrav gozd in kakovosten les. Pod zemljo se skriva še zelo neraziskan svet, ki uravnava dinamiko ogljika v delovanju celotnega ekosistema. Znatno delež monografije je posvečen tudi biološkim osnovam kvalitete lesa. Na primeru najpomembnejših lesnih vrst (jelke in bukve) je prikazano, kako različni okoljski dejavniki vplivajo na kakovost in nastanek lesa. Natančneje je pojasnjeno, kako se odzivajo drevesa na poškodbe, ki jih povzročajo vedno pogostejše vremenske ujme.

Drugi del monografije je posvečen lesu. Natančno je predstavljeno, koliko lesa zraste v slovenskih gozdovih, koliko ga porabimo sami in koliko ga izvozimo. Širšo uporabo lesa pogosto omejujejo slabša naravna odpornost in neustrezne dimenzije lesa. Obe slabosti lahko presežemo bodisi z uporabo ustrezne zaščite bodisi z lepljenjem. Tej tematiki je posvečenih nekaj prispevkov.

Eno izmed trenutno najpomembnejših področij rabe lesa je lesna gradnja. Les je odličen material za objekte sodobne arhitekture. V nekaterih zahodnih državah je delež lesene gradnje pri enostanovanjskih objektih prek 40 %. V Sloveniji je bistveno manjši, vendar močno narašča. Ravno pri lesni gradnji najbolj pride do izraza okoljski pomen lesa, kar je tematika zadnjega izmed prispevkov v drugem delu monografije.

Tretji del monografije je posvečen papirju. Glavna surovina za papir še vedno ostaja les, in kljub uvedbi sodobnih računalniških tehnologij se poraba papirja ni zmanjšala, temveč se celo povečuje. V poglavjih so prikazane lastnosti posameznih papirnih vlaken, možnosti za izboljšanje njihovih lastnosti in izzivi, povezani z njihovim recikliranjem.

V monografiji smo želeli zajeti vsa ključna področja gozdarstva, lesarstva in papirništva in pokazati prepletenost teh področij. Menimo, da je na teh treh področjih treba združiti raziskovalne kapacitete in dvigniti pomen gozdarstva, lesarstva in papirništva, čemur je namenjena tudi skupna monografija. To je prvo delo, ki vsebinsko pokriva celotno proizvodno verigo gozdarstva, lesarstva in papirništva zadnjih 20 let tako v Sloveniji kot širše v Evropi.

doc. dr. Miha HUMAR in prof. dr. Hojka KRAIGHER

The topic of this monograph book is forests and wood, the most important primary raw material available in Slovenia. The monograph entitled Sustainable use of wood in the context of co-natural forest management is the result of the applicative research project financed by the Slovenian Research Agency (ARRS), the first and only project where all three topics from the research field of forestry, wood and paper are covered. Both the project and the monograph deal with wood from its cradle to the grave. The monograph consists of nineteen chapters prepared by authors from three most excellent institutions in Slovenia related to forests, wood and paper, namely: Biotechnical Faculty, Slovenian Forestry Institute and Pulp and Paper Institute.

The most important subjects of this book are forests and wood. It has to be considered that forests cover more than 60 % of the national territory. Since 1875 (737,000 ha), their surfaces have increased by no less than 500,000 ha! In spite of the long tradition in sustainable forestry and wood use in Slovenia, considerably fewer fellings have been recorded than regrowth, resulting in a rapid ageing of forests and loss of wood quality. Therefore it is of national concern to simulate rational use of wood.

The importance of forests and wood increased significantly in recent times, as wood processing is environmentally friendly and not demanding from the energetic point of view. It has to be also considered that wood and wooden product store considerable amounts of carbon. Wood stores carbon through its entire lifespan.

Different points of view are elucidated in 19 scientific chapters of this monograph that covers the entire product chain from forests to wood. The authors of the chapters are acknowledged experts/scientist from the field of forestry, wood and paper. Therefore it is evident that the monograph is the first scientific publication that covers these three closely related fields of activities on equal terms.

In the first few chapters, predominately non-economic functions of forests are presented. This role is becoming increasingly significant. Sustainably managed forest is a guarantee for secure water supply, and it should not be forgotten that forests are the lungs of our planet. Furthermore, forest is much more what is seen at first glance. Soil is the basis for healthy forest and quality of wood.

There is a completely unknown world beneath the ground that influences carbon dynamics in the global system. A considerable part of this monograph is dedicated to the biological background of wood quality. Fir and beech wood were selected as examples where the influence of environmental factors on wood formation and quality was investigated. The response of trees to the wounds, caused by the weather, is elucidated in one of the chapters.

The second part of this book is dedicated to wood. Detailed information on annual regrowth in Slovenian forests, the amounts used in Slovenia, and the amount of exported wood is given. Use of wood is often limited due to the limited natural durability and limited dimensions. We can overcome both weaknesses by using suitable protection or opt for gluing. Two chapters are dedicated to this problem.

One of the most attractive and promising usages of wood is use of wood for construction purposes. Wood is an excellent material to be used in modern architecture. In some European countries, more than 40 % of private houses are made of wood. Market share of wooden houses in Slovenia is indeed considerably lower, but it is increasing significantly. However, it has to be considered that wood is an environmentally friendly material as well. This is the topic of the last chapter in the second part of the book.

Pulp and paper are the topic of the book's third part. The main raw material in the pulp and paper industry is still wood. Despite the informational revolution, the use of paper has not decreased. On the contrary, the consumption of paper is even increasing. The relevant properties of fibres, solutions for their improvement and recycling are also emphasized in this monograph.

The purpose of this book was to elucidate all key topics of the forestry, wood and paper research fields. We strongly believe that research groups working on this topic need to collaborate in order to increase the reputation of the above mentioned research and professional fields. At the end we would like to point out that this is the very first book that covers the entire product chain forestry, wood and paper in the past 20 years in Slovenia as well as in Europe.

doc. dr. Miha HUMAR in prof. dr. Hojka KRAIGHER

Pričujoča monografija je smiselno zaokrožena celota devetnajstih znanstvenih člankov, v katerih je jedrnatno predstavljeno raziskovalno delo, ki ga v tem času opravljajo najeminentnejši slovenski raziskovalci, ki se vsaj z enim segmentom svojega dela uvrščajo na področje gozdarstva, lesarstva in papirništva (raziskovalno področje 4.01 po klasifikaciji Javne agencije za raziskovalno dejavnost Republike Slovenije). Znanstvena spoznanja, predstavljena v tej knjigi, segajo od fiziološko-morfoloških in anatomskih zakonitosti rasti in poškodb lesa prek spoznanj o interakciji dreves s svojim neposrednim okoljem, biotski raznovrstnosti in gospodarski rabi gozda do novih načinov obdelave in predelave lesa v najrazličnejše materiale in izdelke ter izvornih rešitev za reciklažo teh produktov po izteku njihove življenjske dobe. Monografijo smiselno zaključujejo spoznanja o vplivu umne in trajnostne rabe lesa na širše naravno in družbeno okolje, predvsem v luči vedno bolj poudarjenih podnebnih sprememb.

Branje monografije priporočam več kategorijam bralcev. Primarno bi morali delo prebrati vsi znanstveniki in strokovnjaki s področja gozdarstva, lesarstva in papirništva, saj bi tako na preprost način prišli do vzorno urejenega pregleda trenutnega znanstvenega dogajanja na svojem področju.

V drugem krogu bralcev bi morali biti vodilni ljudje v podjetjih z omenjenih področij (ne glede na njihovo izobrazbo ali strokovnost) ter podjetij s področij, ki se navezujejo na gozdarstvo, lesarstvo in papirništvo (gradbeništvo, arhitektura, razvoj novih materialov, proizvodnja embalaže, odstranjevanje in reciklaža odpadkov, itd.). Le dobro, pravilno in celostno informirana vodstva se lahko pravilno odločajo o smereh razvoja svojih podjetij. Ta knjiga jim takšno informacijo vsekakor daje, iz nje pa lahko izluščijo tudi smernice razvoja stroke.

Vsekakor bi knjigo morali prebrati tudi predstavniki vsaj zakonodajne in izvršilne oblasti na lokalni, regionalni in državni ravni ter višji in srednji uslužbenci pristojnih ministrstev (Ministrstvo za kmetijstvo, gozdarstvo in prehrano; Ministrstvo za okolje in prostor; Ministrstvo za visoko šolstvo, znanost in tehnologijo; Ministrstvo za gospodarstvo; Ministrstvo za regionalni razvoj; Služba Vlade za razvoj itd.). Zanje verjetno še bolj kot za gospodarstvenike velja, da ne morejo sprejemati dobrih odločitev, če sami nimajo celostnega pregleda nad tem, kar se dogaja v njihovi branži, širši družbi in okolju. Dandanašnji vsi na deklarativni ravni prisegamo na trajnostni razvoj, ki bi bil v sozvočju s potrebami in zahtevami okolja, ta monografija pa za to poklicanim neposredno ponuja znanja in ukrepe, s katerimi bi uresničevanje teh ciljev približali realnosti.

Nenazadnje pa knjigo priporočam v branje vsem, ki se kakorkoli zanimajo ali ukvarjajo z okoljsko problematiko v najširšem smislu. Trajnostna raba lesa ob hkratnem sonaravnem gospodarjenju z gozdovi je namreč izredno zahtevna paradigma, ki mora biti podprta z bazičnimi raziskavami na vseh področjih, ki se v njo vklapljajo, od temeljnih naravoslovnih (geologija, pedologija, klimatologija, genetika, celična biologija, fiziologija predvsem rastlin in gliv, morfologija, taksonomija in ekologija) prek tehniških (uporabna kemija, gozdarstvo, lesarstvo, papirništvo, arhitektura, industrijsko oblikovanje itd) do družboslovnih in humanističnih (ekonomija, politologija, sociologija, etnologija, varstvo kulturne dediščine). Monografija Trajnostna raba lesa v kontekstu sonaravnega gospodarjenja z gozdovi s svojim pogledom in strukturiranostjo ponuja ne le celosten pregled nad znanstvenim delom v gozdarstvu, lesarstvu in papirništvu, temveč je lahko zelo dober zgled tudi drugim področjem znanosti v Sloveniji, kako smiselno prikazati na videz morda nepovezane raziskave na nekem področju znanosti in ponuditi vsaj nekaj odgovorov na temeljne izzive, s katerimi se danes spoprijema naša družba.

dr. Črtomir Tavzes, znanstveni sodelavec

Direktor

INŠTITUT ZA LESARSTVO IN TRAJNOSTNI RAZVOJ,
raziskovanje, razvoj, svetovanje in izobraževanje d.o.o.

The present monograph is a well-rounded collection of nineteen scientific articles, which succinctly portray research effort by the most eminent Slovene scientists, who devote at least a portion of their interest and resources to the field of forestry, wood science and technology, and pulp and paper science and technology (Research area 4.01 in the classification of the Slovene Research Agency). Scientific discoveries presented in this very fine collection of articles range from the principal processes in wood growth and wounding physiology, morphology, and anatomy to the interaction of trees with their immediate environment, the biodiversity and forest management, as well as to the transformation of wood into various new materials and products, and the recycling thereof at the end of their service life. This edited volume's substance is rounded off by the eye-opening findings of the impact that reasonable and sustainable use of wood could have on the entire society and the environment, especially in the light of increasingly significant climate change.

This extremely informative book should be read by several categories of readers. Scientist and professionals in forestry, wood science, and pulp and paper science ought to be primary readers of this volume, in order to gain the latest, exemplarily edited overview of the scientific development in their field.

The second circle of readers should be the management (both business- and technology-oriented) of the industry in the respective fields, as well as their counterparts in enterprises from the fields related to forestry, wood processing, and pulp and paper production (construction, architecture, design, new materials development, packaging production, waste management, etc.). The right direction of the development of a company can only be made on the basis of solid, true, and wholesome information. Such information is evidently present in this book. In addition to that, an educated reader will be easily able to extract clues on the future development of science and technology in the above mentioned fields.

It is essential that this volume is read by members of at least legislative and executive branches of local, regional, and national government, as well as senior and mid-level career employees of the ministries with the jurisdiction over these three fields (Ministry of Agriculture, Forestry and Food; Ministry of the Environment and Spatial Planning; Ministry of Higher Education, Science and Technology; Ministry of the Economy; Government Office for Development and European Affairs; Government Office for Local Self-Government and Regional Policy). It is probably even more true for this audience than the entrepreneurs that it is impossible for them to accept and implement good decisions and initiatives if they themselves do not have a state-of-the-art insight into the dynamics in their field, society and the environment. In the present day, it is very fashionable to pledge support to the sustainable development that would adhere to the needs and demands of the environment. This book offers the knowledge and suggests the measures that the decision-makers could undertake to bring these goals closer to implementation.

Last but not least, this compendium of articles should be read by anyone who is interested or involved in the issues of the environment, in its broadest sense. The sustainable use of wood in tandem with the sustainable forest management is such a challenging paradigm that it needs to be supported by basic research in all the related fields, from natural science (geology, soil science, climatology, genetics, cell biology, physiology (primarily plant and fungal physiology), morphology, taxonomy, and ecology) through technical disciplines (applied chemistry, chemical and biological engineering, forestry, wood science and technology, pulp and paper science and technology, architecture, industrial design, etc.) to social science and humanities (economics, political science, sociology, ethnology, cultural heritage preservation).

With its premise and structure, the monograph "Sustainable use of wood in the context of co-natural forest management" offers an excellent overview of the current scientific achievements in forestry, wood science and technology, and pulp and paper science and technology. Moreover, this edited volume is a good example to other fields of science in Slovenia of how to coherently present diverse, seemingly unrelated research within a broader field, and how to offer at least some guidance in solving the issues our society faces today.

Črtomir Tavzes, Ph.D., Assistant Research Scientist

Director

Institute of Wood Science and Technology, and Sustainable Development

Monografija **Trajnostna raba lesa v kontekstu sonaravnega gospodarjenja z gozdovi** obravnava les kot najpomembnejše bogastvo Slovenije v zelo širokem kontekstu. Združuje rezultate raziskav temeljnega in aplikativnega raziskovanja s področij gozdarstva, lesarstva in papirništva. Avtorji prispevkov so z vseh treh inštitucij nacionalnega pomena, ki pokrivajo ta področja, in sicer z Biotehniške fakultete, Gozdarskega inštituta Slovenije in Inštituta za celulozo in papir. Poudarek v monografiji je na lesu kot edini naravni surovini, ki jo imamo v Sloveniji v obilju, a je ne znamo primerno in zadosti uporabljati.

Znano je dejstvo, da je Slovenija zaradi naravnih danosti izredno gozdnata dežela in da gozdovi pokrivajo danes že prek 60 % njenega ozemlja. V dolgoletni tradiciji sonaravnega gospodarjenja z gozdom je gozdarjem uspelo in jim še uspeva vzdrževati naše gozdove v dobrem stanju kljub družbeno-ekonomskim turbulencam v bližnji preteklosti. Žal pa uspešnemu gospodarjenju z gozdovi ne sledi raba lesa kljub dobro razvitim tehnologijam njegove predelave v Sloveniji že v preteklosti. V času po osamosvojitvi Slovenije je še posebej pereč zmanjšan obseg predelave in rabe lesa, zato tudi posek močno zaostaja za prirastkom, kar se kaže v staranju gozdov in padcu kakovosti lesa. V času podnebnih sprememb, ki so nastale zaradi izpustov toplogrednih plinov zaradi sprememb v rabi tal in uporabe fosilnih goriv, je pobuda za večjo uporabo lesa in ne celotne biomase lesnatih rastlin zelo primerna in prihaja v pravem času. V monografiji je predstavljen les od njegovega nastanka v gozdu, zgradbe, vplivov na njegovo nastajanje glede na drevesne vrste in okolje. Velikemu in v javnosti že sprejetemu pomenu gozda je treba dodati še pomen rabe lesa kot energetske nepotratne in človeku ter okolju prijazne surovine.

V monografiji 19 prispevkov predstavi celotno verigo od gozda do lesa oziroma papirja. Avtorji poglavij so priznani strokovnjaki s področja gozdarstva, lesarstva in papirništva. Tako je ta monografija prvo znanstveno delo, ki v celoti povezuje ta tri med seboj povezana področja.

Gozdu so v monografiji namenjeni predvsem prispevki, ki obravnavajo negospodarske funkcije gozda. V navezavi s kasnejšimi poglavji, ki obravnavajo predvsem les in papir, so ti prispevki namenjeni odmrlim lesnim ostankom v gozdu in podzemnemu svetu gozda, ki je dosti manj raziskan kot nadzemni del. Na primeru navadne bukve in bele jelke je velik delež monografije posvečen biološkim osnovam tvorbe lesa, ki vplivajo na njegovo kakovost. Prikazan je vpliv različnih okoljskih dejavnikov, ki vplivajo na kakovost in nastanek lesa, vključno s simulacijo podnebnih sprememb.

V poglavju o lesu je natančno predstavljeno, koliko lesa zraste v slovenskih gozdovih, koliko ga porabimo sami in koliko ga izvozimo. Širšo uporabo lesa pogosto omejujejo slabša naravna odpornost in neustrezne dimenzije lesa. Predstavljene so tehnologije in vrste uporabe lesa dobre in slabše kakovosti kot tudi spodbude za povečanje rabe.

V zadnjem delu monografije je predstavljen papir. Zanj ostaja les še vedno glavna surovina in poraba papirja kljub uvedbi sodobnih računalniških tehnologij še vedno narašča. V tem poglavju so prikazane lastnosti in zgradba papirnih vlaken, ki izvirajo iz lesa, možnosti za izboljšanje kvalitete papirja v povezavi z njegovim recikliranjem.

V monografiji so na visoki znanstveni ravni prikazani in smiselno med seboj povezani prispevki s področij gozdarstva, lesarstva in papirništva s poudarkom na nastanku, zgradbi in uporabi lesa, kar gotovo pokriva vrzel v znanstveni in strokovni literaturi v Sloveniji in širše. V enem viru bodo raziskovalci in strokovnjaki lahko našli najnovejše relevantne izsledke raziskav iz zgoraj omenjenih in med seboj povezanih področij, ki so navadno objavljeni parcialno v bolj specializiranih strokovnih in znanstvenih revijah. Monografija je zanimiva tudi za bralce nestrokovnjake, saj v njej dobijo strokovno podprte informacije o nastanku, zgradbi in lastnosti dveh tako pogostih dobrin, kot sta papir in les.

prof. dr. Franc Batič

The monograph *Sustainable use of wood in the context of co-natural forest management* presents wood as the most important natural resource in Slovenia on a very broad scope. It compiles basic and applicable research results from the fields of forestry, wood science and paper. The authors belong to all three research organizations of national importance from these fields of research, i.e. from the Biotechnical Faculty, Slovenian Forestry Institute and the Institute for Cellulose and Paper. The red line is wood as the only abundant natural renewable resource in Slovenia, which, however, is not adequately used and nourished.

Slovenia is a country of forests, which cover over 60% of its territory. Through the long-term tradition of forest management, the foresters have been successful in conserving our forests in a healthy sustainable and predominantly natural state, even though they had to overcome a few socio-economic turbulences in the near past. Unfortunately, the successful forest management has not resulted in a successful use of wood, even though wood technology has been well developed till recently. Especially after gaining national independence, Slovenian wood technology has diminished its production drastically, leading to a decline of the yearly cut with respect to forest growth, which renders consequences to senescence of forests and a decline in wood quality. When facing climate changes, due to emissions of greenhouse gasses which are a consequence of changes in land use & combustion of fossil fuels, the initiative for better utilization of wood, and not whole woody plant biomass, is of utmost importance and coming at a very appropriate time. The monograph presents wood from its growth in the forest, anatomy and influences on its formation with respect to tree species and environmental conditions. The publicly acknowledged great value and multiple functions of forests are thus complemented with use of wood as an energetically non-wasteful and environmentally friendly resource.

In the monograph, 19 contributions present the whole life cycle from the forest to the wood product and paper. The authors are distinguished specialists from the fields of forestry, wood science and paper. Thus, this monograph is the first scientific publication, linking all these three research fields.

The forest is covered predominantly with contributions, presenting its non-economic functions. These contributions present studies of woody debris and belowground processes, which is much less known than the aboveground part. Through the case of common beech and silver fir, an important part of the book is dedicated to biological basis for wood formation, which influences its quality, together with environmental factors and simulation – modelling of climate change impacts.

The chapters on wood are based on the evaluation of wood production in Slovenian forests, its consumption and export. Better supported wood utilization is often hindered by its low natural resilience and inappropriate dimensions of timber. Different technologies and types of utilization of wood are presented, as well as possible stimulations for its greater use.

The last part of the book deals with paper, whose production is still largely based on wood. Characteristics and structure of paper fibers, possibilities for improvement of its quality and its recycling are presented.

The monograph presents a compilation of interlinked chapters from the fields of forestry, wood science and paper, at a high scientific level, thus filling the gaps in knowledge and available literature on the issue in Slovenia and abroad. In a single book, scientists and professionals will be able to find up-to-date relevant research results from these interrelated, linked fields, which are usually published in very different specialized professional and scientific journals. The monograph will provide useful interesting information also for a general audience, learning from it on development and characteristics of the widespread goods, such as forest, wood and paper.

prof. dr. Franc Batič

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