

Prospects of Research on Cable Logging in Forest Engineering Community

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Abstract – Nacrtak

An analysis of researches on cable logging carried out in the past 12 years (2000–2011) as found in the scientific literature at international level is proposed in order to evaluate which have been the main topics of interest of the researchers and to evaluate the evolution of the research in the field of cable logging in the next future. International scientific literature on cable logging was extracted from the main databases, scientific journals and conference proceedings on forest engineering. A total of 244 references were retrieved and used to create a library implemented in Thompson Reuter EndNote® software. The analysis of the references through the use of some descriptors has allowed to define that in the period 2000–2011 most of the attention of forest engineers interested in cable logging was attracted by the study of the efficiency of the cable system, followed by the study and analysis of the impact produced by or derived from the environmental components by the use of cable logging. Cable system simulation has played an important role, especially because of the variety of methodologies developed by forest engineers. Even if the number of references indicates some interest in cable system mechanics, most of the references deal with studies and tests about ropes, mainly synthetic ones. Carriage, yarders and supports seem to have been less attractive as objects of study. Ergonomics and safety in the field of cable logging have revealed a growing attention especially in the recent years, while an almost complete lack of interest in education and training was observed. Starting from such considerations, some prospects of the cable logging research for the next future were envisaged.

Keywords: forest engineering, cable logging, scientific literature

1. Introduction – Uvod

A way to assess the activity of a scientific community is to analyze its production in term of publications in scientific journals, communications at conferences, reports, etc. If such assessment is focused on a specific subject, the amount of the scientific production can be considered as a sort of indicator about the interest of scientists on such subject. Furthermore it is possible to focus the main issues that have directed the activity of the scientists and hence to evaluate which would be the prospects for the future.

These considerations have driven the analysis of the researches on cable logging carried out in the past 12 years (2000–2011) as found in the scientific literature at international level. To retrieve the international scientific literature on cable logging the following databases were queried:

- ⇒ Google Scholar,
- ⇒ Science Direct,
- ⇒ CAB Abstracts,
- ⇒ Current Contents,
- ⇒ Ingenta Connect,
- ⇒ Forest Science Database,
- ⇒ AGRIS International Information System for the Agricultural Sciences and Technology,
- ⇒ IUFRO On-line Library,
- ⇒ USDA National Forest Service Library,
- ⇒ USDA Treesearch Forest Service Research and Development.

Each database was queried using the following keywords: »cable logging«; »cable yarding«; »cable crane«; »cable yarder«; »tower yarder« and the search for the records was only made considering those fully

written in English. The author was aware that this constraint excluded some important information sources of scientific literature on cable logging, e.g. the ones produced in Korea and in Japan, and so the survey was likely to be limited, but as explained below, the necessity to evaluate each record required that the linked manuscript was written in English. A further search was made on the main scientific journals related to forest engineering and available on the net and in the conference proceedings on forest engineering.

For each reference the manuscript was examined and, if of interest to the research, it was imported into Thompson Reuter EndNote® software tool (2010) to create a library. Each reference contains the main bibliographic information together with the URL (Uniform Resource Locator), where a printed sample of the paper is available, and one or two keywords to allow the following elaboration on the information content of the library. For the purpose of the research, the keywords must be considered as a sort of descriptors useful to manage the references according to the analysis carried out; from this point of view two main subjects were considered: »Cable system« and »Cable logging«. The former includes all the descriptors dealing with cable extraction considered as a system; the latter considers the descriptors that refer to the relationship between the logging method and the environment, the operators and the management.

Cable system efficiency: the descriptor or keyword refers to papers in which productivity and/or cost of cable system are considered;

Cable system design: the descriptor or keyword refers to papers in which design, arrangement and patterns of cable system are considered;

Cable system planning: the descriptor or keyword refers to papers in which not only the planning approach for cable system is considered, but also the relationship with forest road network and ancillary infrastructures;

Cable system simulation: the descriptor or keyword refers to papers in which simulation techniques and modeling are considered to different extent;

Cable system mechanics: the descriptor or keyword refers to papers in which mechanical features of cable system are concerned; in order to increase the discriminating capacity, second-level descriptors were introduced: »yarder«, »carriage«, »rope«, »support«, each one referring to mechanical features of a specific component of the cable system;

Cable logging impact: the descriptor or keyword refers to papers in which the disturbance produced by

cable logging on environmental resources is considered; in order to increase the discriminating capacity, second-level descriptors were introduced: »vegetation«, »soil«, »water«, »air«, each one referring to the main environmental resource involved in the analysis of the cable logging impact;

Cable logging ergonomics and safety: the descriptor or keyword refers to papers in which ergonomics and safety of cable logging, as a whole or as individual components, are considered;

Cable logging education and training: the descriptor or keyword refers to papers in which educational and training approaches are applied to cable logging both as educational programs and teaching tools.

Cable logging management: the descriptor or keyword refers to papers in which the relationship between cable logging and management practices is considered especially from the contractor's perspective.

The library was set up with a total of 243 recorded references; even though the number of records did not cover all the scientific literature about cable logging because of the English language constraint adopted in the literature review, the sample obtained could be considered valuable and fulfilling the aim of the research. The 243 recorded references refer to papers produced by a total of 354 authors.

2. Analysis of the research on cable logging – *Analiza istraživanja iznošenja drva žičarama*

2.1 Time distribution – *Vremenska raspodjela*

The 243 recorded references are not homogeneously distributed in the time period considered (2000–2011); as reported in Table 1, the average number of references per year was 20.3, but in one year the number of references per year was very much greater. This is the case of the year 2001 when 51 references were registered; the reason of such number is due to the fact that in 2001 a conference devoted to harvesting with cable systems was organized in Austria, accounting for 28 out of the total of 2001 references. Another year that deserves to be considered, not for the total number of references but for the source of such references, is the year 2011: even though the number of references was almost the same as the average of the period (20 vs. 20.3), 12 of them belong to the same conference. A similar situation was recorded in the year 2007, when half (11) of the annual references (22) came from the same conference.

Table 1 Recorded references in the period 2000–2011**Tablica 1.** Zabilježene objave u razdoblju 2000–2011.

Year – Godina	References – Objave
2000	17
2001	50
2002	11
2003	17
2004	24
2005	3
2006	17
2007	21
2008	12
2009	22
2010	29
2011	20
Total – Ukupno	243
Mean – Prosječno	20.3

2.2 Scientific literature sources – *Izvori znanstvene literature*

The main sources of scientific literature were the conference proceedings (Table 2), followed by the journal articles and reports. Under the form of book sections only two references were retrieved, while no book was available concerning cable logging.

One gets the distinct impression that, compared to 10 or 20 years before the analyzed period, cable logging tended to be regarded less as the subject of a book, and more as the subject of journal articles or conference proceedings. From a certain point of view,

Table 2 Scientific literature sources**Tablica 2.** Izvori znanstvene literature

Source – Izvori	References – n Objave – n
Journal article – Članak u časopisu	76
Conference proceedings – Zbornik radova	153
Book section – Poglavlje u knjizi	2
Report – Izvještaj	12
Total – Ukupno	243

writing and publishing a book seems to be a time consuming activity, and however in the field of cable logging, fundamental books like the ones published in the '70s and '80s of the past century are highly needed.

2.3 »Cable system« – »Žični sustavi«

The analysis of each reference related to the »Cable system« through the main descriptor showed that the »Cable system efficiency« is the most frequent descriptor (Table 3) with 78 references out of 172. The second largest descriptor is »Cable system simulation«. It can be concluded that the interest of the researchers was mainly devoted to the analysis of cable system from productivity and/or economic point of view and it should be noted that 15 references out of 80 dealing with the descriptor »Cable system efficiency« are related to experiments carried out in Turkey, highlighting the interest of the Turkish forest engineering researchers in such studies.

»Cable system simulation«, accounting for around 21% of the references related to the »Cable system«, reveals its potential as a research issue. Cable system simulation is a broad term that considers Optimization Techniques, DDS (Decision Support System), Network Analysis, Dynamic Model, Finite Element Modeling; fields of application include cable logging layout, cable crane location, forest road spacing (using cable logging), cable tension analysis, fuel consumption, productivity, harvesting cost.

»Cable system planning« accounts for 13% of the references related to the »Cable system« and generally refers to a harvest layout planning approach for cable-based system. Some references also refer to updated photogrammetric techniques through which the reliability of the data used in planning logging operation can be enhanced. Logging planning is considered essential to successful implementation of cable systems and also to effective implementation of BMPs (Best Management Practices).

To analyze »Cable system mechanics«, which accounts for 16% of the references of the »Cable system«, it is necessary to consider four second-level descriptors, which represent the main components of a cable system from a mechanical point of view (Table 4).

It is impressive to note that the »rope« descriptor includes 20 out of 28 references of the main descriptor (»Cable system mechanics«); it seems that most of the scientific interest on the mechanics of the cable system has been drawn by ropes if compared to other components. This situation can be understood if one considers that 16 references refer to research papers dealing with synthetic ropes; starting from the end of the last

Table 3 Recorded references in the period 2000–2011 broken down according to different main descriptors related to »Cable system«**Tablica 3.** Zabilježene objave teme »žični sustavi« u razdoblju 2000–2011. razdijeljene prema različitim deskriptorima

Year Godina	Cable system – Žični sustavi				
	Efficiency Djelotvornost	Design Projektiranje	Simulation Simulacija	Planning Planiranje	Mechanics Mehanika
	n				
2000	6	1	1	1	2
2001	11	4	8	10	4
2002	5	0	3	0	1
2003	2	0	4	2	4
2004	6	1	4	2	2
2005	0	0	0	1	0
2006	8	0	2	1	2
2007	9	0	2	1	3
2008	6	0	2	1	2
2009	12	1	1	1	2
2010	8	0	7	3	1
2011	5	0	2	0	5
Total – Ukupno	78	7	36	23	28

Table 4 Recorded references in the period 2000–2011 related to »Cable system mechanics« descriptor and broken down according to second-level descriptors**Tablica 4.** Zabilježene objave vezane uz deskriptor »mehanika žičnih sustava« u razdoblju 2000–2011. te razdijeljene prema drugoj razini deskriptora

Year Godina	Rope – Uže	Carriage – Kolica	Yarder – Žičara	Support – Potporanj
	n			
2000	1	0	0	1
2001	2	0	0	1
2002	3	0	0	0
2003	2	0	1	0
2004	0	0	0	0
2005	2	0	0	0
2006	2	0	0	0
2007	2	0	0	1
2008	2	0	0	0
2009	1	0	0	0
2010	2	1	0	0
2011	1	3	0	0
Total – Ukupno	20	4	1	3

century synthetic ropes have been introduced into forest use and, due to their potential to replace steel wire rope for selected logging operations, they have required comprehensive analysis and evaluations.

During the same period only four references consider steel wire rope and their behavior during operation.

2.4 »Cable logging« – »Iznošenje drva žičarama«

»Cable logging« accounts for 71 references and the descriptor »Cable logging impacts« covers 44 of them (62%). The descriptor »Cable logging ergonomics and safety« includes 19 (27%) references, while the references covered by the descriptors »Cable logging education and training« and »Cable logging management« are minimal.

»Cable logging impacts« refers to a wide range of papers, some of them strictly reporting the consequences of cable logging on soil or on residual stands, other analyzing the effects of forest practices, in which cable logging is considered, on the environmental components, including also visual disturbance.

Four second-level descriptors were used to improve the accuracy of the classification: »vegetation«, »soil«, »water« and »air« (Table 6). The data from the

table clearly reveal that the references mainly refer to the impact of cable logging on vegetation and on soil, while very few of them are linked to the impact on water and air. However it must be said that the boundary between soil impact and water impact is really vague because of the interaction that links soil disturbance to sediment production and hence stream water quality.

Regarding the impact of the cable logging on the air, it is interesting to observe that the papers dealing with such topic are quite new, the oldest ones being published in 2006.

»Cable logging ergonomics and safety« accounts for 17 references, many of which are related to the workload benefit using synthetic ropes and radio controlled chokers. It is interesting to note that such references refer to the last two years of the considered period and include 10 out of 17 papers.

It is disheartening to notice that »Cable logging education and training« contains only three references, two of them referring to papers published at the beginning of the period!

The descriptor »Cable logging management« has offered the opportunity to include references that deal with the connection between cable logging and man-

Table 5 Recorded references in the period 2000–2011 broken down according to different main descriptors related to »Cable logging«

Tablica 5. Zabilježene objave teme »iznošenje drva žičarama« u razdoblju 2000–2011. razdijeljene prema različitim deskriptorima

Year <i>Godina</i>	Cable logging – <i>Iznošenje drva žičarama</i>			
	Impact <i>Utjecaj</i>	Ergonomics and safety <i>Ergonomija i sigurnost</i>	Education and training <i>Obrazovanje i obuka</i>	Management <i>Upravljanje</i>
	n			
2000	3	0	1	2
2001	7	3	1	2
2002	1	1	0	0
2003	5	0	0	0
2004	8	0	0	1
2005	2	0	0	0
2006	4	0	0	0
2007	2	2	0	2
2008	1	0	0	0
2009	4	1	0	0
2010	4	6	0	0
2011	3	4	1	0
Total – <i>Ukupno</i>	44	17	3	7

Table 6 Recorded references in the period 2000–2011 related to »Cable logging impact« descriptor and broken down according to second-level descriptors**Tablica 6** Zabilježene objave vezane uz deskriptor »utjecaj iznošenja drva žičarama« u razdoblju 2000–2011. te razdijeljene prema drugoj razini deskriptora

Year Godina	Vegetation – Vegetacija	Soil – Tlo	Water – Voda	Air – Zrak
	n			
2000	3	0	0	0
2001	2	5	0	0
2002	0	1	0	0
2003	4	1	0	0
2004	4	3	1	0
2005	0	1	0	1
2006	1	0	1	2
2007	1	1	0	0
2008	0	1	0	0
2009	2	1	0	1
2010	2	2	0	0
2011	0	1	1	1
Total – Ukupno	19	17	3	5

agement practices and to provide the contractors' perspective about different problems that must be considered when cable logging is carried out. The references covered by the descriptor »Cable logging management« do not refer to scientific papers in the strict sense of the word, but they contribute to understanding how cable logging is managed and which the daily problems are that must be faced by contractors.

3. Future prospects of the research on cable logging – *Budućnost istraživanja iznošenja drva žičarama*

The author is aware of the limits of the library he has set up due to the language constraint and to the number of information sources that were queried; he is also aware of the subjectivity that may have affected the evaluation of the main content of each paper trying to assign the proper descriptor. Anyway the methodology and the analysis meet the requirements of a scientific approach and hence it is possible to draw some conclusions and to point out some prospects to the forest engineering community.

In the period 2000–2011 most of the attention of forest engineers interested in cable logging was at-

tracted by the study of the efficiency of the cable system, followed by the study and analysis of the impact produced by or derived from the environmental components by the use of cable logging. Cable system simulation has played an important role, especially for the variety of methodological approaches developed by forest engineers; similar considerations can be made when cable system planning is concerned. Different conclusions can be drawn analyzing cable system mechanics; even if the number of references indicates some interest in such topic, it must be emphasized that most of the references deals with studies and tests about ropes, mainly synthetic ones. Carriage, yarders and supports seem to have been less attractive as objects of study. Ergonomics and safety in the field of cable logging have revealed a growing attention especially in the recent years, while education and training were affected by an almost total lack of interest.

In order to suggest which vision of the cable logging research will characterize the years to come, it is important to recall a concept by Prof. Heinemann (2000), that still retains its full validity after a decade and can be repeated again as a basis for the development of cable logging: it must be considered that individual technologies will not be enough to face the challenges of the coming years but total systems, which

include expertise, procedures, goods and services, and equipment as well as organizational and managerial procedures, must be envisaged.

Starting from such holistic considerations, the prospects of the cable logging research for the next future could include:

- ⇒ To develop new materials for the ropes (both synthetic and steel wire ropes) in order to increase the rope strength, allowing an increment of system transport capacity;
- ⇒ To develop mechatronics application on carriages and yarders, increasing work efficiency and ergonomics and empowering human-machine interface;
- ⇒ To improve the feasibility of computerized methods for cable logging planning;
- ⇒ To improve mathematical methods to optimize structural analysis of a cable structure;
- ⇒ To optimize the energy consumption, reducing as far as possible the energy derived from fossil fuels and increasing the utilization of electric energy and gravitational energy;
- ⇒ To investigate the cable assisted ground vehicle technology that represents a border area between terrestrial and air logging systems;
- ⇒ To improve the use of tools like Life Cycle Assessment (LCA) to evaluate the environmental issues of cable-based technologies;
- ⇒ To improve education and training in cable logging operations, developing educational methodologies and teaching tools that acknowledge the critical importance of the learner in all aspects of the learning process.

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Sažetak

Perspektiva istraživanja iznošenja drva žičarama u šumarskoj inženjerskoj zajednici

Namjera je analize provedenih istraživanja iznošenja drva žičarama u posljednjih dvanaest godina (2000–2011), zasnovane na znanstvenim međunarodnim objavama, ocjena glavnih istraživanih tema te procjena razvoja istraživanja vezanih uz šumske žičare u budućnosti. Međunarodna znanstvena literatura prikupljena je iz baza podataka znanstvenih časopisa, odnosno zbornika radova iz šumarskoga inženjerstva. Pretražene su ove baze podataka: 1) Google Scholar, 2) Science Direct, 3) CAB Abstracts, 5) Current Contents, 6) Ingenta Connect, 7) Forest Science Database, 8) AGRIS International Information System for the Agricultural Sciences and Technology, 9) IUFRO On-line Library, 10) USDA National Forest Service Library, 11) USDA Treesearch Forest Service Research and Development. U pretraživanju smo se služili ključnim riječima: iznošenje drva žičarom («cable logging», «cable yarding»), žičara («cable crane», «cable yarder»), stupna žičara («tower yarder»). Pretraživanje se odnosilo isključivo na radove napisane engleskim jezikom. Dodatno je pretraživanje obuhvatilo dostupne objave s mrežnih stranica znanstvenih časopisa i međunarodnih znanstvenih savjetovanja iz šumarskoga inženjerstva.

Ukupno su 243 objave uvrštene te korištene za stvaranje zbirke u računalnom programu Thompson Reuter EndNote®. Svakoj su objavi pridružene jedna ili dvije ključne riječi radi daljnje razradbe sadržaja zbirke. U istraživanju su se ključne riječi smatrale deskriptorima pomoću kojih se objave mogu razvrstavati tijekom analiza prema potrebi. S toga su gledišta ključne riječi razvrstane u dvije glavne teme: »sustav žičara« i »iznošenje drva žičarama«. Prva tema uključuje sve deskriptore koji iznošenje drva žičarom opisuju kao sustav: »djelotvornost žičnih sustava«, »projektiranje žičnih sustava«, »planiranje žičnih sustava«, »simulacija žičnih sustava«, »mehanika žičnih sustava«. Za analizu »mehanike žičnih sustava« dodana su četiri deskriptora druge razine koji opisuju glavne sastavnice žičnoga sustava s mehaničke točke gledišta: »žičara«, »kolica«, »uže«, »potporanj«. Druga tema uključuje deskriptore koji se odnose na: 1) utjecaj načina (metode) iznošenja drva na okoliš («utjecaj iznošenja drva žičarama»), 2) rukovatelje žičarama («ergonomija i sigurnost u radu pri iznošenju drva žičarom« i »izobrazba i obuka za iznošenje drva žičarom«), 3) upravljanje («upravljanje iznošenjem drva žičarom»). Radi lakšega razlučivanja deskriptoru »utjecaj iznošenja drva žičarama« dodana su četiri deskriptora druge razine, od kojih svaki opisuje jedan od glavnih okolišnih resursa uključenih u analizu utjecaja iznošenja drva žičarom: »vegetacija«, »tlo«, »voda« i »zrak«.

Objave uvrštene u istraživanje nisu ravnomjerno raspoređene u promatranom razdoblju (2000–2011); prosječno su bile 20,3 objave godišnje, s izuzetkom 2001. godine kada ih je bilo mnogo više (50) zbog održane konferencije posvećene organizaciji pridobivanja drva žičarama. Potrebno je izdvojiti i 2007. i 2011. godinu ne zbog broja objava, već zbog činjenice da većina objava potječe s dviju konferencija održanih tih godina. Glavni su izvori znanstvenih objava bili zbornici radova, zatim članci u časopisu te izoještaji. Objave u obliku knjiga ili poglavlja iz knjiga gotovo su zanemarive.

Primjenom deskriptora u analizi objava zaključeno je da su u razdoblju od 2000. do 2011. godine šumarski inženjeri zainteresirani za iznošenje drva žičarama najviše istraživali djelotvornost žičnih sustava te zatim utjecaj iznošenja drva žičarom na različite sastavnice okoliša. Simulaciji je žičnih sustava također pridana važnost, pretežno u njihovim različitim varijantama izvedbe koje su razvili šumarski inženjeri. Iako broj objava pokazuje da postoji zanimanje za mehaniku žičnih sustava, većina se znanstvenika bavi istraživanjem užadi, posebice sintetičke. To se može objasniti činjenicom da se, zahvaljujući mogućnosti da zamijeni čeličnu užad prilikom određenih radova pridobivanja drva, sintetička užad u šumarstvu počela upotrebljavati krajem prošloga stoljeća te zbog toga zahtijeva opsežne analize i procjene. Kolica, žičare i potpornji rjeđe su bili predmetom istraživanja. Što se tiče utjecaja iznošenja drva žičarom na okoliš, objave su se uglavnom bavile utjecajem na vegetaciju i tlo, a samo nekoliko njih utjecajem na vodu i zrak. Treba ipak priznati da je teško razgraničiti utjecaj na tlo i na vodu od ostaloga štetnoga utjecaja jer oštećenje (gaženje) tla uzrokuje nastanak i taloženje sedimenta u vodotocima te posljedično narušava kakvoću vode. Ergonomiji i sigurnosti pri iznošenju drva žičarama posljednjih se godina pridaje sve veća pažnja, dok za izobrazbu i obuku ne postoji značajan interes.

Na temelju tih razmatranja predviđa se sljedeća budućnost istraživanja iznošenja drva žičarama:

- ⇒ Razvoj novih materijala za užad (i sintetičku i čeličnu) radi povećanja čvrstoće i nosivosti užadi,
- ⇒ Razvoj upravljanja mehaničkim sklopovima na kolicima i žičarama, s povećanjem radne djelotvornosti i ergonomije te poboljšanjem upravljanja strojevima,

- ⇒ Povećanje izvedivosti računalnih metoda planiranja iznošenja drva žičarom,
- ⇒ Poboljšanje matematičkih metoda za optimizaciju strukturnih analiza žičnih sustava,
- ⇒ Optimizacija potrošnje energije, smanjenje uporabe energije iz fosilnih goriva na najmanju moguću mjeru, povećanje iskoristivosti električne energije i energije gravitacije,
- ⇒ Istraživanje tehnologije privlačenja drva po tlu kretnim vozilima potpomognutim žičarom koja predstavljaju prijelaz između zračnih i po tlu kretnih sustava,
- ⇒ Povećanje uporabe alata poput Analize životnoga ciklusa (LCA) za procjenu štetnoga djelovanja žičnih tehnologija na okoliš,
- ⇒ Poboljšanje izobrazbe i obuke za radove na iznošenju drva žičarom razvojem edukacijskih metodologija i alata za učenje koji uzimaju u obzir važnost učenika u čitavom procesu učenja.

Ključne riječi: šumarsko inženjerstvo, iznošenje drva žičarom, znanstvena literatura

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