

Prospects of Research on Cable Logging in Forest Engineering Community

Raffaele Cavalli

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 Treeresearch 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.

4. References – *Literatura*

EndNote Rel. X4.0.2. Thompson Reuter

Heinimann, H. R., 2000: Forest operations under mountainous conditions. In: Forests in Sustainable Mountain Development – a State of Knowledge Report for 2000, M.F. Price and N. Butt, Editors. CABI Publishing: Wallingford, UK. Vol. IUFRO Research Series No. 5: p. 224–230.

5. References library – *Literatura zbirke*

Acar, H. H., 2006: Timber Extraction by Cable Cranes, Monorail and Chute Systems in Turkish Forestry. In: Proceedings of COFE Conference, July 30 – August 2. Coeur d'Alene Resort, Coeur d'Alene, Idaho.

Acar, H. H., Eroglu, H., Ozkaya, M. S., 2010: An investigation on roundwood extraction and determination of the physical damages on residual trees and seedlings due to logging operation using URUS MIII forest skyline on snow. In: Proceedings of FORMEC Conference, July 11–14, Padova, Italy.

Acar, H. H., Topalak, O., Eroglu, H., 2006: Forest skylines in Turkish forestry. Meh. şumar. 2001–2004, Special Issue of the Journal Nova meh. şumar., Vol. 26(2005), Issue 2: 137–140.

Acar, H. H., Unver, S., Ozkaya, M. S., Kilic, H., 2011: Determination of efficiency of the forest skylines in Artvin Forest Region of Turkey. In: Proceedings of FORMEC Conference, October 9–13, Graz, Austria.

Ackermann, P., Talbot, B., 2004: Reverting urban exotic pine forests to Macchia and indigenous forest vegetation using cable-yarders on the slopes of Table Mountain, South Africa. In: Proceedings of Conference Forestry Serving Urbanised Societies, August 27–30, Copenhagen, Denmark.

Adnan, A. M., 2002: Cable logging technique using a mobile tower yarder for low impact logging in Malaysian forest. In: Proceedings of International seminar on new roles of plantation forestry requiring appropriate tending and harvesting operations, September 29 – October 5, Tokio, Japan.

Amishev, D., Evanson, T., 2010: Innovative methods for steep terrain harvesting. In: Proceedings of FORMEC Conference, July 11–14, Padova, Italy.

Anderson, L., Temen, K. L., 2000: Cable Thinning as a Business Partnership between Landowner and Contractor. In: Proceedings of International Mountain Logging and 10th Pacific Northwest Skyline Symposium, March 28 – April 1, Corvallis, Oregon.

Aricak, B., 2002: Transportation of timber by cable systems in Turkish forestry. In: Proceedings of International seminar on new roles of plantation forestry requiring appropriate tending and harvesting operations, September 29 – October 5, Tokio, Japan.

Arriagada, R., Cabbage, F. W., Abt, K. L., Huggett, R. J. Jr., 2008: Estimating harvest costs for fuel treatments in the West. Forest Products Journal 58(7–8): 24–30.

Aruga, K., Tasaka, T., Yoshioka, T., 2008: Long-term feasibility of timber and forest biomass resource extraction in a mountainous area – reducing harvesting costs with new harvesting systems. In: Proceedings of IUFRO All-D3 Conference, June 15–20, Sapporo, Japan.

Asikainen, A., Stampfer, K., Talbot, B., 2010: An evaluation of skyline systems in Norwegian conditions using discrete-event simulation. In: Proceedings of Precision Forestry Symposium, March 1–3, Stellenbosch, South Africa.

Asikainen, A., Stampfer, K., Talbot, B., Belbo, H., 2010: Simulation of skyline systems in Norwegian conditions. In: Proceedings of 2010 Nordic Baltic Conference on Forest Operations, October 20–22, Honne, Norway.

Aulerich, S., 2000: Commercial Thinning with Cable Yarding Systems. In: Proceedings of COFE Conference, September

11–14, Joint Meeting with Canadian Woodlands Forum, Kelowna, British Columbia.

Aulerich, S., 2000: Raising a Spar Tree – Technique of the Past Solves Challenge of Today. In: Proceedings of COFE Conference, September 11–14. Joint Meeting with Canadian Woodlands Forum, Kelowna, British Columbia.

Bailey, P., 2007: A contractor's perspective on skyline thinning equipment and logging innovations. In: Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium, April 1–6, Corvallis, Oregon.

Baker, S., Sloan, H., Visser, R., 2001: Cable logging in Appalachia and opportunities for automated yarder equipment. In: Proceedings of COFE Conference. July 15–19, Snowshoe Resort, Snowshoe, West Virginia.

Baldini, S., Calvani, P., Picchio, R., 2001: Winch use in work with extra light cable systems in South-Central Italy. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.

Beese, W. J., Dunsworth, B. G., Zielke, K., Bancroft, B., 2003: Maintaining attributes of old-growth forests in coastal BC through variable retention. *The Forestry Chronicle* 79(3): 570–578.

Beschta, R. L., Jackson, W. L., 2008: Forest practices and sediment production in the Alsea watershed study. *Hydrological and Biological Responses to Forest Practices*: 55–66.

Beschta, R. L., Rhodes, J. J., Kauffman, J. B., Gresswell, R. E., Minshall, G. W., Karr, J. R., Perry, D. A., Hauer, F. R., Frissell, C. A., 2004: Postfire management on forested public lands of the western United States. *Conservation Biology* 18(4): 957–967.

Bolding, M. C., Lanford, B. L., Kellogg, L. D., 2003: Forest fuel reduction: current methods and future possibilities. In: Proceedings of COFE Conference, September 7–10. Atlantic Oakes by the Sea Resort, Bar Harbor, Maine.

Borz, S. A., Birda, M., Ignea, G., Oprea, I., 2011: Technological aspects regarding timber exploitation using Mounty 4100 cable yarder. In *Serie II: Forestry-Wood Industry-Agricultural Food Engineering*.

Boswell, B., 2001: Partial cutting with a cable yarding system in coastal British Columbia. *Advantage* 42(2).

Boyce, J. A., 2005: Blending stand-level treatments and landscape planning with opportunities for research in a working forest. Gen. Tech. Rep. PNW-GTR-635, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, 389 p.

Caglar, S., 2009. An investigation on productivity of Gantner yarder at windblown forest stand in Turkey. In: Proceedings of FORMEC Conference, June 2–5, Schmalleberg, Germany.

Caglar, S., Acar, H. H., 2009: A review on the forest skylines and their productivities at mountainously eastern Black Sea region of Turkey. In: Proceedings of FORMEC Conference, June 21–24, Kostelec nad Cernymi lesy, Czech Republic.

Cavalli, R., Grigolato, S., 2010: Influence of characteristics and extension of a forest road network on the supply cost of forest woodchips. *Journal of Forest Research* 15(3):202–209.

Cavalli, R., Grigolato, S., Lubello, D., 2006: Planning logging systems through site analysis. In: Proceedings of Precision Forestry Symposium, March 5–10, Stellenbosch, South Africa.

Cavalli, R., Ientile, F., Menegus, G., 2004: Cable crane use under sustainable forest management in North-eastern Italian Alps. In: Proceedings of Conference Cable yarding suitable for sustainable forest management, September 23, Idrija, Slovenia.

Cavalli, R., Lubello, D., 2006: Firewood cable yarding on steep terrain in Alpine conditions. In: Proceedings of FORMEC Conference, September 24–28, Sofia, Bulgaria.

Cavalli, R., Menegus, G., De Benedet, B., 2001: Cable crane utilization in the close-to-nature silviculture in the upper Piave river valley (Belluno province, Northern Italy). In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.

ChihLung, C., YuLun, S., BingShu, G., ShaoJyun, H., ShihYao, G., 2009: Operational efficiency of thinning for the mixed plantation stand located at Tai-Ping-Shan working circle. *Forest Products Industries* 28(3): 149–166.

Chung, W., 2002: Optimization of cable logging layout using a heuristic algorithm for network programming. In: Proceedings of COFE Conference, June 16–20. Auburn University, Auburn, Alabama.

Chung, W., Seielstad, C., Sessions, J., 2008: Sloperunner2.0: a computer program for cable logging unit planning. In: Proceedings of IUFRO All-D3 Conference, June 15–20, Sapporo, Japan.

Chung, W., Sessions, J., 2003: A computerized method for determining cable logging feasibility using a DEM. In: Proceedings of COFE Conference, September 7–10. Atlantic Oakes by the Sea Resort, Bar Harbor, Maine.

Chung, W., Sessions, J., Heinimann, H. R., 2001: Optimization of cable harvesting equipment placement and road locations using digital terrain models. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.

Chung, W., Sessions, J., Heinimann, H. R., 2004: An application of a heuristic network algorithm to cable logging layout design. *International Journal of Forest Engineering* 15(1).

Chung, W., Sessions, J., Holub, J., 2007: Sloperunner 1.0: a program to evaluate the effectiveness of landing and road locations for cable logging. In: Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium, April 1–6, Corvallis, Oregon.

Clinton, B. D., 2011: Stream water responses to timber harvest: Riparian buffer width effectiveness. *Forest ecology and management* 261: 979–988.

- Covert, S. A., Robichaud, P. R., Elliot, W. J., Link, T. E., 2005: Evaluation of runoff prediction from WEPP-based erosion models for harvested and burned forest watersheds. *Transactions of the ASAE* 48(3):1091–1100.
- Deal, R. L., Hennon, P. E., Orlikowska, E. H., D'Amore, D. V., 2004: Stand dynamics of mixed red alder-conifer forests of southeast Alaska. *Canadian Journal of Forest Research* 34(4):969–980.
- Dicus, C., 2003: Fueling loading and potential fire behavior after selective harvest in coast redwood stands. In: *Proceedings of 2nd International Wildland Fire Ecology and Fire Management Congress*, November 16–20, Orlando, Florida.
- Drews, E. S., Hartsough, B. R., Doyal, J. A., Kellogg, L. D., 2001: Harvester-forwarder and harvester-yarder systems for fuel reduction treatments. *International Journal of Forest Engineering* 12(1): 81–91.
- Dykstra, D. P., Monserud, R. A., 2007: Influence of Forest Operations on Timber Quality. In: *Proceedings of International Conference Forest Growth and Timber Quality: Crown Models and Simulation Methods for Sustainable Forest Management*, August 7–10, Portland, Oregon.
- Eker, M., Acar, H. H., 2001: Gantner skyline for timber extraction in Turkish forestry. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Eklund, A., Wing, M. G., Sessions, J., 2009: Evaluating economic and wildlife habitat considerations for snag retention policies in burned landscapes. *Western Journal of Applied Forestry* 24(2): 67–75.
- Epstein, R., Weintraub, A., Sapunar, P., Nieto, E., Sessions, J. B., Sessions, J., Bustamante, F., Musante, H., 2006: A combinatorial heuristic approach for solving real-size machinery location and road design problems in forestry planning. *Operations Research* 54(6): 1017–1027.
- Eroglu, H., 2009: Timber harvesting by URUS M III forest skyline on snow in steep terrain; a case from Artvin, Turkey. In: *Proceedings of FORMEC Conference*, June 2–5, Schmalenberg, Germany.
- Eroglu, H., Ozkaya, M. S., Acar, H. H., Karaman, A., Yolasig-maz, H. A., 2010. An investigation on roundwood extraction of *Fagus orientalis* Lipsky, *Abies nordmanniana* (Stew.) Spach. and *Picea orientalis* (L.) Link. by Urus M III forest skyline on snow. *African Journal of Biotechnology* 8(6): 1082–1089.
- Evanson, T., Amishev, D., 2010. Productivity impacts of bunching for yarder extraction. In: *Proceedings of FORMEC Conference*, July 11–14, Padova, Italy.
- Fabiano, F., Magagnotti, N., Neri, F., Piegai, F., Spinelli, R., 2010: Safety in mechanised forest operations: a Tuscan project. In: *Proceedings of FORMEC Conference*, July 11–14, Padova, Italy.
- Fabiano, F., Marchi, E., Neri, F., Piegai, F., 2011: Skyline tension analysis in yarding operation: cases studies in Italy. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Fight, R. D., 2003: Users guide for STHARVEST: software to estimate the cost of harvesting small timber. Gen. Tech. Rep. PNW-GTR-582, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, 11 p.
- Fight, R. D., Hartsough, B. R., Noordijk, P., 2006: Users guide for FRCS: fuel reduction cost simulator software. Gen. Tech. Rep. PNW-GTR-668, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, 23 p.
- Fischbacher, M., Mairhofer, M., 2007: New skyline logging technology for yarding and tree processing with a two person crew. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Fladl, H., Loschek, J., 2001: Employment of contractors in cable crane operations in Austria. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Gandaseca, S., Hulusi, A., Yoshimura, T., 2001: Occupational safety and health of forestry workers cable harvesting in Turkey. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Garland, J. J., 2001: The basis for productivity improvement in cable harvesting from human resources. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Garland, J. J., Pilkerton, S. J., 2007: Synthetic rope reduces workloads in logging. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Garland, J. J., Sessions, J., Pilkerton, S. J., Hartter, J., Leonard, J. M., 2003: Synthetic rope to replace wire rope in mountain logging operations. In: *Proceedings of AUSTRO 2003 Conference*, October, 5–9, Schlägl, Austria.
- Garland, J. J., Sessions, J., Pilkerton, S. J., Leonard, J. M., Hartter, J., 2003: Synthetic rope to replace wire rope in logging. In: *Proceedings of 2nd Forest Engineering Conference*, May 12–15, Växjö, Sweden.
- Garland, J. J., Sessions, J., Pilkerton, S. J., Stringham, B., 2001: Synthetic rope used in logging: Some Potentials. In: *Proceedings of COFE Conference*, July 15–19, Snowshoe Resort, Snowshoe, West Virginia.
- Ghaffariyan, M. R., Sessions, J., 2011. Error Impact of Regression Models on Forest Road Spacing. *Silva Balcanica* 1(12):97–111.
- Ghaffariyan, M. R., Stampfer, K., Sessions, J., 2010: Optimal road spacing of cable yarding using a tower yarder in South-

- ern Austria. *European Journal of Forest Research* 129(3): 409–416.
- Ghaffariyan, M. R., Stampfer, K., Sessions, J., 2009: Using network analysis to optimize forest road network for cable logging. In: *Proceedings of FORMEC Conference*, June 2–5, Schmalleberg, Germany.
- Ghaffariyan, M. R., Stampfer, K., Sessions, J., 2009: Production Equations for Tower Yarders in Austria. *International Journal of Forest Engineering* 20(1): 17–21.
- Ghaffariyan, M. R., Stampfer, K., Sessions, J., 2010. Optimal road spacing of cable yarding using tower yarder in Southern Austria. *European Journal of Forest Research* 129(3): 409–416.
- Ghaffariyan, M. R., Stampfer, K., Sessions, J., Durston, T., Kuehmaier, M., Kanzian, C. H., 2010: Road network optimization using heuristic and linear programming. *Journal of Forestry Science* 56(3): 137–145.
- Gingras, J. F., 2000: Update on the viability of cable yarding in eastern Canada. *Advantage* 1(9).
- Giovannini, G., Cavalli, R., Grigolato, S., 2009: Improving felling and thinning for coppice and young high forest stands in alpine condition – the case of Trento province. In: *Proceedings of FORMEC Conference*, June 2–5, Schmalleberg, Germany.
- Gomi, T., Sidle, R. C., Swanston, D. N., 2004: Hydrogeomorphic linkages of sediment transport in headwater streams, Maybeso Experimental Forest, southeast Alaska. *Hydrological processes* 18(4): 667–683.
- Greulich, F. E., 2000: Calculation and use of effective external boundary and related setting parameters in cable yarding production estimation. Gen. Tech. Rep. NC-205, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. pp 7.
- Greulich, F. E., 2003: Transportation networks in forest harvesting: early development of the theory. In: *Proceedings of International seminar on new roles of plantation forestry requiring appropriate tending and harvesting operations*, September 29 – October 5, Tokyo, Japan.
- Grulois, S., 2007: Cable yarding in France: past, present and perspective. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Gumus, S., Acar, H. H., Ozturk, M., 2010: Evaluation of consecutive skylines yarding and gravity skidding systems in primary forest transportation on steep terrain. *Journal of Environmental Biology* 31(1–2): 213–218.
- Hakso, A., 2009: Biofuels from precommercial thinning operations – A feasibility survey. In: *Proceedings of 1st Annual Forest Engineering, Resources and Management Department Graduate Student Symposium*, June 4, Corvallis, Oregon.
- Halpern, C. B., McKenzie, D., 2001: Disturbance and post-harvest ground conditions in a structural retention experiment. *Forest ecology and management* 154(1–2): 215–225.
- Hamilton, P. S., 2008: Life expectancy of synthetic fibre main-lines in cable skidding applications. In: *Advantage* 10(10).
- Han, H. S., 2007: Economics of Soil Disturbance. In: *Proceedings of Conference on Volcanic-Ash-Derived Forest Soil in the Inland Northwest: Properties and Implications for Management and Restoration*, November 9–10, 2005, Coeur d'Alene, ID
- Han, H. S., Kellogg, L. D., 2000: Damage characteristics in young Douglas-fir stands from commercial thinning with four timber harvesting systems. *Western Journal of Applied Forestry* 15(1): 27–33.
- Hartley, D. S., Han, H. S., 2007: Effects of alternative silvicultural treatments on cable harvesting productivity and cost in western Washington. *Western Journal of Applied Forestry* 22(3): 204–212.
- Hartsough, B. R., Zhang, X., Fight, R. D., 2001: Harvesting cost model for small trees in natural stands in the interior northwest. *Forest Products Journal* 51(4): 54–61.
- Hartter, J., Garland, J. J., 2006: Synthetic rope end connections for use in timber harvesting. *International Journal of Forest Engineering* 17(1): 39–51.
- Hartter, J., Leonard, J. M., Garland, J. J., Pilkerton, S. J., 2006: Research on synthetic rope and its future in timber harvesting. *New Zealand Journal of Forestry* 51(2): 23–30.
- Haynes, H., Visser, R., 2001: Productivity improvements through professional training in Appalachian cable logging operations. In: *Proceedings of The International Mountain Logging and 11th Northwest Pacific Skyline Symposium*, December 10–12, Seattle, Washington.
- Haynes, H., Visser, R., Sloan, H., 2002: A Case Study on Cable Yarding for a Stream Habitat Treatment and the Utility of a »Roadside« Log Sale. In: *Proceedings of COFE Conference*, June 16–20, Auburn University, Auburn, Alabama.
- Heinimann, H. R., 2001: Approaches to the design of forest cable systems. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Heinimann, H. R., 2000: Forest Operations under Mountainous Conditions. In: *Forests in Sustainable Mountain Development – a State of Knowledge Report for 2000*, edited by M. F. Price and N. Butt. Wallingford: CABI Publishing.
- Heinimann, H. R., 2004: Forest Operations under Mountainous Conditions. In: *Encyclopedia of Forest Sciences*, edited by J. Burley, J. Evans and J. Youngquist. Amsterdam: Elsevier Academic Press.
- Heinimann, H. R., Stampfer, K., 2003: Harvest Layout Planning for High-Altitude Protection Forests. In: *AUSTRO 2003 Conference Proceedings*, October, 5–9, Schlaegl, Austria.
- Heinimann, H. R., Stampfer, K., Loschek, J., Caminada, L., 2001: Perspectives on Central European Cable Yarding Systems. In: *Proceedings of The International Mountain Logging and 11th Northwest Pacific Skyline Symposium*, December 10–12, Seattle, Washington.

- Hessburg, P., Goheen, D. J., Koester, H., 2001: Association of black stain root disease with roads, skid trails, and precommercial thinning in Southwest Oregon. *Western Journal of Applied Forestry* 16(3):127–135.
- Horek, P., Mauer, P., 2001: Forest cableways in shelterwood system. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Horek, P., Novak, J., Neruda, J., 2009: Forest cableways and their use in forest management. In: *Proceedings of FORMEC Conference*, June 2–5, Schmallingenberg, Germany.
- Hosseini, S. M., Madjnonian, B., Nieuwenhuis, M., 2000: Damage to Natural Regeneration in the Hyrcanian Forests of Iran: A Comparison of Two Typical Timber Extraction Operations. *International Journal of Forest Engineering* 11(2): 69–73.
- Huettnner, W., 2001: Aspects of mechanical engineering for cable systems. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Hulusi, A., Unver, S., 2004: The environmental impact assessment of timber extraction by cable cranes, monorail and chute systems in Turkish forestry. In: *Science Bulletin*, edited by Ukrainian National Forestry University.
- Ishikawa, T., Ishidoh, Y., Yamazaki, H., Shiba, M., Yarugi, Y., 2004: Development of simplified manual cable yarding methods for thinning operations by volunteer workers. *Journal of the Japan Forest Engineering Society* 18(4): 259–262.
- Ito, T., Uemura, T., 2011: Automatic control for a self-propelled carriage to enable one-man cable yarding. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Jaross, W. S., 2001: Techniques for Preparing Alternative Road Access Policies for Steep and Mountainous Terrain. In: *Proceedings of The International Mountain Logging and 11th Northwest Pacific Skyline Symposium*, December 10–12, Seattle, Washington.
- Johnson, L. R., Lippke, B., Marshall, J. D., Comnick, J., 2005: Life-cycle impacts of forest resource activities in the Pacific Northwest and Southeast United States. *Wood and fiber science* 37: 30–46.
- Kato, A., Schiess, P., 2007: LIDAR-derived tree parameters for optimal cable logging system design. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Kerstetter, J. D., Lyons, J. K., 2001: Logging and agricultural residue supply curves for the Pacific Northwest. Washington State University Energy Publication.
- King, R., 2007: Long span skyline logging: past application and current niche. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Kirk, P. M., Sullman, M. J. M., 2001: Heart rate strain in cable hauler choker setters in New Zealand logging operations. *Applied Ergonomics* 32(4): 389–398.
- Kirth, R., Schimier, S., Nemestóthy, N., Sperrer, S., 2007: Further developments of synthetic ropes for logging applications in forestry. In: *Proceedings of FORMEC Conference*, October 7–11, Vienna and Heiligenkreutz, Austria.
- Klepac, J., Reutebuch, S. E., 2003: Preliminary Soil Disturbance Assessment of a Skyline Logging Operation Performing Five Silvicultural Prescriptions. In: *Proceedings of ASAE International Meeting*, July 27–30, Las Vegas, Nevada.
- Klun, J., Robek, R., 2009. GPS-based design of skyline corridors and software solutions for analyzing of cableway system. In: *Proceedings of FORMEC Conference*, June 2–5, Schmallingenberg, Germany.
- Klvac, R., Fischer, R., Skoupy, A., 2009: Emissions from the »Larix« cableway system operation phase. In: *Proceedings of FORMEC Conference*, June 2–5, Schmallingenberg, Germany.
- Knobloc, C., 2011: Cost-effective short-wood logging cable way system for lowland stands. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Kolsek, M., 2004: Cable yarding in Slovenian State Forests. In: *Proceedings of Conference Cable yarding suitable for sustainable forest management*, September 23, Idrija, Slovenia.
- Košir, B., 2000: Cable crane skidding courses for professional workers and private forest owners in Slovenia. In: *Proceedings of Conference Working Under a Dynamic Framework – Forest Ownership Structures and Extension*, October 4–8 1999, Bled, Slovenia.
- Košir, B., 2001: Optimal line lengths when skidding wood with the Syncrofalke cable crane in Slovenian conditions. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Krogstad, F., Schiess, P., 2004: The allure and pitfalls of using LiDAR topography in harvest and road design. In: *Proceedings of Joint Conference of IUFRO 3.06 Forest Operations under Mountainous Conditions and 12nd International Mountain Logging Conference*, June 13–16, Vancouver, Canada.
- Krpan, A., Poršinsky, T., Šusnjar, M., 2001: Timber extraction technologies in Croatian mountainous selection forests. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Kurosaki, H., Iwaoka, M., Minematsu, H., 2008: Intervals to determine extra yarding distance of small scale cable yarding systems. In: *Proceedings of IUFRO All-D3 Conference*, June 15–20, Sapporo, Japan.
- Laffan, M., Jordan, G., Duhig, N., 2001: Impacts on soils from cable-logging steep slopes in northeastern Tasmania, Australia. *Forest ecology and management* 144(1–3): 91–99.

- Largo, S., Han, H. S., Johnson, L., 2004: Productivity and Cost Evaluation for Non-guyline Yarders in Northern Idaho. In: Proceedings of COFE Conference, April 27–30, Clarion Resort on the Lake, Hot Springs, Arkansas.
- LeDoux, C. B., Gopalakrishnan, B., Pabba, R. S., 2002: An expert system for estimating production rates and costs for hardwood group-selection harvests. Proceedings 13th Central Hardwood Forest Conference, April 1–3, Urbana-Champaign, Illinois.
- LeDoux, C. B., Huyler, N. K., 2000: Cost comparisons for three harvesting systems operating in northern hardwood stands. Res. Pap. NE-715, U.S. Department of Agriculture, Forest Service, Northeastern Research Station, pp 4.
- LeDoux, C. B., Wilkerson, E., 2008: Assessing the ecological benefits and opportunity costs of alternative stream management zone widths for eastern hardwoods. Proceedings 2007 National Silviculture Workshop, May 7–10, Ketchikan, Arkansas.
- Leitner, T., Visser, R., Stampfer, K., 2010: Efficiency and ergonomic benefits of using radio controlled chokers in cable yarding. *Croatian Journal of Forest Engineering* 31(1): 1–10.
- Leonard, J. M., 2000: Combining Cut-to-Length and Cable Yarding Operations. In: Proceedings of International Mountain Logging and 10th Pacific Northwest Skyline Symposium, March 28 – April 1, 1999 Corvallis, Oregon.
- Leonard, J. M., Garland, J. J., Pilkerton, S. J., 2003: Evaluation of synthetic rope for static rigging application in cable logging. In: Proceedings of COFE Conference, September 7–10, Atlantic Oakes by the Sea Resort, Bar Harbor, Maine.
- Lewis, J., Keppeler, E. T., 2004: Trends in streamflow and suspended sediment after logging, North Fork Caspar Creek. In: Proceedings of The Redwood Region Forest Science Symposium: What does the future hold?, March 15–17, Albany, California.
- Lexter, M. J., Stampfer, K., Vacik, H., Hochbichler, E., Limbeck-Lilienau, B., Hagauer, D., Durrstein, H., Spork, J., 2002: A computer based decision support tool for timber harvest planning under multiple objectives in steep terrain. In: Proceedings of Conference Mountain Forests: Conservation and Management, July 28 – August 1, Vernon, British Columbia.
- Li, Y., Wang, J., Miller, G., McNeel, J. F., 2006: Production economics of harvesting small-diameter hardwood stands in central Appalachia. *Forest Products Journal* 56(3): 81–86.
- Li-hai, W., 2000: Environmentally sound timber extracting techniques for small tree harvesting. *Journal of Forestry Research* 11(4): 269–272.
- Limbeck-Lilienau, B., 2003: Residual stand damage caused by mechanized harvesting systems. In: Proceedings of AUSTRO 2003 Conference, October, 5–9, Schlaegl, Austria.
- Limbeck-Lilienau, B., Lexter, M. J., Stampfer, K., Vacik, H., Palmetzhofer, D., Hagauer, D., Hochbichler, E., Durrstein, H., Spork, J., 2003: CONES – A computer based decision support tool to explore stand management options in steep terrain. In: Proceedings of Decision support for multiple purpose forestry. A transdisciplinary conference on the development and application of decision support tools for forest management, April 23–25, Vienna, Austria.
- Loschek, J., 2001: Development of mechanized logging. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Loschek, J., 2004: Cable yarding management in mountainous areas – ecological and economical aspects on silviculture. In: Proceedings of Conference Cable yarding suitable for sustainable forest management, September 23, Idrija, Slovenia.
- Lyons, C. K., 2007: A design criterion for guyed backspars. In: Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium, April 1–6, Corvallis, Oregon.
- Lyons, C. K., 2008: Considering Cable Stretch in Logging Applications. *International Journal of Forest Engineering* 19(1): 29–35.
- Magaud, P., 2011: SIMULCABLE, a new software to optimise the line implantation for cable yarding. In: Proceedings of FORMEC Conference, October 9–13, Graz, Austria.
- Mahon, R., 2000: Experience in Cable Thinning. In: Proceedings of International Mountain Logging and 10th Pacific Northwest Skyline Symposium, March 28 – April 1, 1999 Corvallis, Oregon.
- Manzone, M., Balsari, P., 2010: Assessing the performance of a cable crane using single cable. In: Proceedings of FORMEC Conference, July 11–14, Padova, Italy.
- Marenče, J., Vadjal, J., Košir, B., 2009: Bucking of conifers using the woody H60 processor on the Syncrofalke 3 T cable yarder in Alpine foothills. *Zbornik gozdarstva in lesarstva* (88): 3–10.
- Markewitz, D., 2006: Fossil fuel carbon emissions from silviculture: impacts on net carbon sequestration in forests. *Forest ecology and management* 236(2): 153–161.
- Masi, M., Nannicini, C., Amati, R., Fabiano, F., Neri, F., Piegai, F., Magagnotti, N., Spinelli, R., Laurendi, V., Pirozzi, M., 2010: Safety and Prevention in Mechanised Forest Operations: a Tuscan Project. In: Proceedings of International Conference Ragusa SHWA 2010, September 15–18, Ragusa, Italy.
- McNeel, J. F., 2000: Modeling Production of Longline Yarding Operations in Coastal British Columbia. *International Journal of Forest Engineering* 11(1): 29–38.
- Messingerova, V., Stanovsky, M., Ferencik, M., Kovacik, P., 2009: Technological planning in cableway terrains in Slovakia. In: Proceedings of FORMEC Conference, June 21–24, Kostelec nad Cernymi lesy, Czech Republic.
- Murphy, G., Brownlie, R., Kimberley, M., Beets, P., 2009: Impacts of forest harvesting related soil disturbance on end-of-rotation wood quality and quantity in a New Zealand radiata pine forest. *Silva Fennica* 43(1): 147–160.

- Murphy, G., Firth, J. G., Skinner, M. F., 2004: Long-term impacts of forest harvesting related soil disturbance on log product yields and economic potential in a New Zealand forest. *Silva Fennica* 38(3): 279–289.
- Murphy, G., Vanderburg, M., 2007: Modelling the economics of extended shift and 24/7 forest harvesting. *New Zealand Journal of Forestry* 52(2): 15.
- Nemestóthy, N., 2010: Synthetic fibre ropes for forestry use – criteria for the replacement of fibre ropes. In: *Proceedings of FORMEC Conference*, July 11–14, Padova, Italy.
- Nemestóthy, N., 2011: Synthetic fibre ropes for forestry use – further developments in finding criteria for the replacement state of fibre ropes. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Neri, F., Piegai, F., Marchi, E., Nati, C., 2009: Cableway logging operations and residual harvesting: cases study in windthrow areas in the Eastern Alps – Italy. In: *Proceedings of FORMEC Conference*, June 2–5, Schmallingenberg, Germany.
- Newton, M., Cole, E. C., 2006: Harvesting impacts on understory regeneration in two-storied Douglas-fir stands. *Western Journal of Applied Forestry* 21(1): 14–18.
- Nitami, T., Suk, S., Kataoka, A., Mitsuyama, T., 2011: Tower yarder operation in Japan and the performance analysis by GPS-based system. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Nitteberg, M. A., 2003: Mechanised harvesting in cable operation. In: *Proceedings of 2nd Forest Engineering Conference*, May 12–15, Växjö, Sweden.
- Nitteberg, M. A., 2007: From Off-road to On-road harvesting in steep terrain in Norway. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Nitteberg, M. A., Stampfer, K., Kindernay, D., 2010: Continuous work strain measurement in cable yarder rigging. In: *Proceedings of 2010 Nordic Baltic Conference on Forest Operations*, October 20–22, Honne, Norway.
- Nitteberg, M. A., Talbot, B., 2011: Developing a new yarder-controlled mechanical slack-pulling carriage for double-drum winches. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Oberholzer, F., Howe, D., 2007: The use of monocables in the harvesting of small timber: a South African perspective. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Oka, M., Inoue, M., Kobayashi, H., 2006: Studies of the pattern classification of the logging systems for thinning on the basis of the applicability of forestry machines and features of logging system. *Journal of the Japan Forest Engineering Society* 21(2): 115–124.
- Okonski, J., 2004: Skyline Systems in Appalachia – 101 Tribulations. In: *Proceedings of COFE Conference*, April 27–30, Clarion Resort on the Lake, Hot Springs, Arkansas.
- Olund, D., 2001: The Future of Cable Logging. In: *Proceedings of The International Mountain Logging and 11th Northwest Pacific Skyline Symposium*, December 10–12, Seattle, Washington.
- Ottaviani Aalmo, G., Kyllö, N. O., Talbot, B., 2011: The Owen mini 400: a unique 1: 3 scale electrically powered tower yarder for research, training and demonstration. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Ottaviani Aalmo, G., Nitteberg, M. A., Stampfer, K., Talbot, B., 2011: Workload benefits of using synthetic rope strawline in cable yarder rigging in Norway. *Croatian Journal of Forest Engineering* 32(2): 561–569.
- Ottaviani Aalmo, G., Nitteberg, M. A., Stampfer, K., Talbot, B., 2011: Workload benefits of using synthetic ropes in cable yarder rigging in Norway. In: *Proceedings of FORMEC Conference*, October 9–13, Graz, Austria.
- Owende, P. M., Tiernan, D., Ward, S. M., Lyons, J. K., 2001: Is there a role for cable extraction on low gradient sensitive sites? In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Ozturk, M., Aykut, T., Acar, H. H., 2001: Time analyses on Koller K300 cable system on difficult terrain in Turkey. In: *Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains*, June 18–24, Ossiach, Austria.
- Ozturk, M., Senturk, N., Hulusi, H. H., 2007: Forest skylines in Turkey. In: *Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium*, April 1–6, Corvallis, Oregon.
- Ozturk, T., 2009: Productivity of timber extraction by Urus MIII cable crane from selective spruce forests. *African Journal of Agricultural Research* 4(9): 852–858.
- Ozturk, T., Demir, M., 2007: Transporting of spruce timbers by URUS MIII cable system from selective forests of Artvin region. *Building and environment* 42(3): 1278–1282.
- Ozturk, T., Senturk, N., 2006: Extraction of spruce timber by Gantner cable crane from selective forests of Artvin region. *Croatian Journal of Forest Engineering* 27(1): 59–66.
- Park, S-J., Kim, J-W., Park, M-S., Song, T-Y., Cho, K-H., 2006: An analysis of the yarding operation system with a mobile tower-yarder in Korea. In: *Proceedings of COFE Conference*, July 30 – August 2, Coeur d'Alene Resort, Coeur d'Alene, Idaho.
- Park, S-J., Son, B-S., Lee, S-H., Han, S-Y., Kim, D-G., 2008: Analysis of a mobile tower-yarder operation in Korea. In: *Proceedings of IUFRO All-D3 Conference*, June 15–20, Sapporo, Japan.
- Pertlik, E., 2009: Do Synthetic Ropes change the design principles of standing skylines? In: *Proceedings of COFE Conference*, June 15–18, Kings Beach (Lake Tahoe), California.
- Phillips, E. J., 2001: Alternative harvesting for visually sensitive areas. *Advantage* 2(42).

- Pičman, D., Pentek, T., Poršinsky, T., 2001: Relation between forest roads and extraction machines in sustainable forest management. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Pilkerton, S. J., Garland, J. J., Hartter, J., 2004: Applications of synthetic rope for improved ergonomic, economic and environmental performance in mountainous logging. In: Proceedings of 2004 International Mountain Logging Conference, June 14, Vancouver, British Columbia.
- Pilkerton, S. J., Garland, J. J., Leonard, J. M., Sessions, J., 2004: Synthetic rope use in logging winching applications. In: Proceedings of 2004 International Mountain Logging Conference, June 14, Vancouver, British Columbia.
- Pilkerton, S. J., Garland, J. J., Sessions, J., Stringham, B., 2001: Prospects for using synthetic rope in logging: First look and future research. In: Proceedings of The International Mountain Logging and 11th Northwest Pacific Skyline Symposium, December 10–12, Seattle, Washington.
- Pollini, C., Schmiedhofer, J., 2001: The use of cable cranes in South Tyrol in the light of recent legislation. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Pyles, M. R., Lyons, K. C., 2001: Analysis of unguyed spar-trees. *International Journal of Forest Engineering* 12(2): 11–17.
- Rahim, A. R., Shahwahid, M. S., Zariyawati, M. A., 2009: A comparison analysis of logging cost between conventional and reduce impact logging practices. *International Journal of Economics and Management* 32(2): 354–366.
- Rashin, E. B., Clishe, C. J., Loch, A. T., Bell, J. M., 2006: Effectiveness of timber harvest practices for controlling sediment related water quality impacts. *JAWRA Journal of the American Water Resources Association* 42(5): 1307–1327.
- Rieger, G., 2001: Costs and performance of a Koller K300 yarder. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Rivera, S., Kershner, J. L., Dobrowski, J. P., 2010: Evaluation of the surface erosion from different timber yarding methods in Honduras. *Revista Arvore* 34(4): 577–586.
- Robek, R., Medved, M., 2001: Implementation of cable logging requirements in environmentally sound road construction. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Roberts, B., 2004: A comparison of landslide rates following helicopter and conventional cable-based clear-cut logging operations in the Southwest Coast Mountains of British Columbia. *Geomorphology* 61(3–4): 337–347.
- Sabadyr, A., Sibtsev, S., 2001: Characteristics of the cable yarding system application in the Ukrainian Carpathians. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Saidi-Mehrabad, M., 2002: Application of Markov Processes to the machine delays analysis. *International Journal of Engineering, Transactions B: Applications* 15: 63–72.
- Saravi, A. A., Lyons, K. C., 2004: Finite element modeling of guyed backspars in cable logging. *Canadian Journal of Forest Research* 34 (4):817–828.
- Saunders, J. C., 2001: Current trends in cableway systems in the United Kingdom. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Schiess, P., 2001: Road management strategies to reduce habitat impacts – A case for engineered cable yarding operations and harvest schedules. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Schiess, P., 2004: Forest transportation issues in relation to stream habitat conservation: trade offs between environmental and economic concerns. In: Proceedings of Conference Cable yarding suitable for sustainable forest management, September 23, Idrija, Slovenia.
- Schiess, P., Krogstad, F., 2003: LiDAR-based topographic maps improve agreement between office-designed and field-verified road locations. In: Proceedings of COFE Conference, September 7–10, Bar Harbor, Maine.
- Schmimer, K. R., Nemestóthy, N., Sperrer, S., 2009: Further developments of synthetic ropes for logging applications in forestry. In: Proceedings of FORMEC Conference, June 2–5, Schmallingenberg, Germany.
- Senturk, N., Ozturk, T., Demir, M., 2007: Productivity and costs in the course of timber transportation with the Koller K300 cable system in Turkey. *Building and environment* 42(5): 2107–2113.
- Sessions, J., Chung, W., Heinimann, H. R., 2001: New algorithms for solving large-scale transportation planning problems. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Sloan, H., 2001: Appalachian hardwood logging systems: managing change for effective BMP implementation. In: Proceedings of COFE Conference, July 15–19, Snowshoe, West Virginia.
- Smeets, P., 2007: The use of high performance synthetic fibers in synthetic ropes for logging applications in the forestry. In: Proceedings of FORMEC Conference, October 7–11, Vienna and Heiligenkreutz, Austria.
- Smidt, M., 2011: A description of forest industries and occupations with focus on forestry workers' jobs and injury

- and illness surveillance. In: Proceedings of COFE Conference, June 12–15, Quebec City, Canada.
- Solmie, D. K., Kellogg, L. D., Kiser, J. D., Wing, M. G., 2003: Comparing strategies for skyline corridor layout. In: Proceedings of COFE Conference, September 7–10, Bar Harbor, Maine.
- Sonne, E., 2006: Greenhouse gas emissions from forestry operations: a life cycle assessment. *Journal of environmental quality* 35(4): 1439–1450.
- Spinelli, R., Magagnotti, N., Lombardini, C., 2010: Performance, capability and costs of small-scale cable yarding technology. *Small-Scale Forestry* 9(1): 123–135.
- Spinelli, R., Magagnotti, N., Nati, C., 2010: Benchmarking the impact of traditional small-scale logging systems used in Mediterranean forestry. *Forest ecology and management* 260(11): 1997–2001.
- Spinelli, R., Visser, R., 2008: Analyzing and estimating delays in harvester operations. *International Journal of Forest Engineering* 19(1): 34–61.
- Stampfer, K., 2002: Combining harvester with cable yarder on steep terrain thinning operations. In: Proceedings of International seminar on new roles of plantation forestry requiring appropriate tending and harvesting operations, September 29 – October 5, Tokio, Japan.
- Stampfer, K., 2004: Perspectives on whole tree cable yarding systems for thinning operation in Austria. In: Proceedings of Conference Cable yarding suitable for sustainable forest management, September 23, Idrija, Slovenia.
- Stampfer, K., Karpf, F., Visser, R., 2010: Efficiency and ergonomic advantages of synthetic rope for guying cable yarders. In: Proceedings of 2010 Nordic Baltic Conference on Forest Operations, October 20–22, Honne, Norway.
- Stampfer, K., Leitner, T., Visser, R., 2009: Efficiency and ergonomic benefits of using radio controlled chokers in cable yarding. In: Proceedings of FORMEC Conference, June 21–24, Kostelec nad Cernymi lesy, Czech Republic.
- Stampfer, K., Leitner, T., Visser, R., 2010: Efficiency and ergonomic benefits of using radio controlled chokers in cable yarding. *Croatian Journal of Forest Engineering* 31(1): 1–9.
- Stampfer, K., Lexter, M. J., 2001: Multicriteria evaluation of thinning operations on steep terrain. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Stampfer, K., Lexter, M. J., Vacik, H., Hochbichler, E., Durrstein, H., Spork, J. 2001: CONES – A computer based multiple criteria decision support tool for timber harvest planning in steep terrain. In: Proceedings of COFE Conference, July 15–19, Snowshoe, West Virginia.
- Stampfer, K., Visser, R., Kanzian, C. H., 2006: Cable corridor installation times for European yarders. *International Journal of Forest Engineering* 17(2): 71–77.
- Streif, A., 2001: View of the contractor for forest companies. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Sullman, M. J. M., Kirk, P. M., 2001: Harvesting wind damaged trees: a study of the safety implications for fallers and choker setters. *International Journal of Forest Engineering* 12(2): 67–77.
- Suzuki, Y., 2000: Damage to residual stands from thinning with short-span tower yarders: re-examination of wounds after five years. *Journal of Forest Research* 5(3): 201–204.
- Suzuki, Y., Shiobara, M., Kondo, M., 2000: Plane-Type Logging Cable Systems in Japan – Past, Present and Future. In: Proceedings of International Mountain Logging and 10th Pacific Northwest Skyline Symposium, March 28 – April 1, Corvallis, Oregon.
- Thompson, M., Stander, H., John, S., 2008: GuylinePC: An Interactive Guyline Tension Analysis Program for Guyed Logging Towers. *Western Journal of Applied Forestry* 23(3): 133–141.
- Torgersen, H., 2000: Endurance of compacted steel wire ropes. *International Journal of Forest Engineering* 11(2): 43–49.
- Torgersen, H., 2002: Service life of compacted steel wire ropes on varying block sheave diameters. *International Journal of Forest Engineering* 13(1): 51–56.
- Torgersen, H., Lisland, T., 2002: Excavator-based cable logging and processing system: a norwegian case study. *International Journal of Forest Engineering* 13(1): 11–16.
- Tsioras, P. A., Rottensteiner, C., Stampfer, K., 2011: Analysis of accidents during cable yarding operations in Austria 1998–2008. *Croatian Journal of Forest Engineering* 32(2): 549–560.
- Tucek, J., Pacola, E., 2001: Skyline yarding distance modeling for logging in mountains. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Tunay, M., Melemez, K., 2001: Work performance of Koller K300 cable system on difficult terrain in Turkey. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.
- Unver, S., Acar, H. H., 2009: Evaluation of residual tree damage in sloping areas due to harvesting operations by manually. *Austrian Journal of Forest Science* 126(3): 119–132.
- Unver, S., Ozkaya, M. S., Kilic, H., Acar, H. H., 2011: Determination of efficiency of the forest skylines in Artvin Forest Region of Turkey. In: Proceedings of FORMEC Conference, October 9–13, Graz, Austria.
- Vacik, H., Lexter, M. J., Palmetzhofer, D., Stampfer, K., Limbeck-Lilienau, B., 2004: Application of the spatial decision support system CONES for regeneration planning in moun-

tain forests. In: Proceedings of Joint Conference of IUFRO 3.06 Forest Operations under Mountainous Conditions and 12nd International Mountain Logging Conference, June 13–16, Vancouver, Canada.

Vacik, H., Lexter, M. J., Palmethzofer, D., Stampfer, K., Limbeck-Lilienau, B., 2004: Application of the spatial decision support system CONES for regeneration planning in mountain forests. In: Proceedings of Conference Cable yarding suitable for sustainable forest management, September 23, Idrija, Slovenia.

Valente, C., Spinelli, R., Hillring, B. G., 2011: LCA of environmental and socio-economic impacts related to wood energy production in alpine conditions: Valle di Fiemme (Italy). *Journal of Cleaner Production* 19(17–18): 1931–1938.

Vana, T. T., Giambelluca, T. W., Sutherland, R. A., Senock, R. S., 2001: Impacts of Forest Harvesting on Soil Hydraulic Characteristics at Hakalau, Hawaii. In: Proceedings of American Geophysical Union Fall Meeting, December 10–14, San Francisco, California.

Vasilev, V., Rossnev, B., Kitanova, S., Alexandrov, A., Raev, I., Tsakov, H., Dimitrov, V., Grozeva, M., Petrova, R., Popov, G., 2003: Possibilities for the use of the light cable crane Pioneer for removal of faggot-wood at gravitation regime of work. In: Proceedings of International scientific conference marking 75 years of the Forest Research Institute of the Bulgarian Academy of Sciences, October 11–14, Sofia, Bulgaria.

Visser, R., 2010: Landings size and characteristics. *Future Forests Research*. University of Canterbury, School of Forestry, pp 8.

Visser, R., Adams, J., 2002: Risk management of steep terrain harvesting. In: Proceedings of COFE Conference, June 16–20, Auburn, Alabama.

Visser, R., Baker, S., Sloan, H., 2001: Cable logging opportunities in the Appalachian mountains. In: Proceedings of Workshop New trends in wood harvesting with cable systems for sustainable forest management in the mountains, June 18–24, Ossiach, Austria.

Visser, R., Spinelli, R., Magagnotti, N., 2010: Landing size and landing layout in whole-tree harvesting operations in New Zealand. In: Proceedings of FORMEC Conference, July 11–14, Padova, Italy.

Wing, M. G., Kellogg, L. D., 2001: Using a Laser Range Finder to assist harvest planning. In: Proceedings of First Inter-

national Precision Forestry Cooperative Symposium, June 17–20, Seattle, Washington.

Worrell, W. C., Bolding, M. C., Aust, W. M., 2010: Comparison of potential soil erosion following skyline yarding versus tracked skidding on bladed skid trails in the Appalachian Region of Virginia. In: Proceedings of COFE Conference, June 6–9, Auburn, Alabama.

Worrell, W. C., Bolding, M. C., Aust, W. M., 2011: Potential soil erosion following skyline yarding versus tracked skidding on bladed skid trails in the Appalachian Region of Virginia. *Southern Journal of Applied Forestry* 35(3): 131–135.

Yoshimura, T., Hartsough, B. R., 2007: Conceptual evaluation of harvesting systems for fuel reduction and biomass collection on steep terrain using system dynamics. In: Proceedings of International Mountain Logging and 13th Pacific Northwest Skyline Symposium, April 1–6, Corvallis, Oregon.

Yoshimura, T., Hartsough, B. R., 2010: Simulation-based validation of new conceptual cable harvesting systems. In: Proceedings of FORMEC Conference, July 11–14, Padova, Italy.

Yoshimura, T., Hartsough, B. R., 2010: Validation of a new conceptual cable harvesting system using an independent device for lateral yarding. In: Proceedings of COFE Conference, June 6–9, Auburn, Alabama.

Yoshimura, T., Otsu, H., Hartsough, B. R., 2011: Developing and validating the automatic log transfer mechanism between two carriage. In: Proceedings of FORMEC Conference, October 9–13, Graz, Austria.

Zambelli, P., Lora, C., Ciolli, M., Spinelli, R., Tattoni, C., Vitti, A., Zatelli, P., 2010: A FOSS4G model to estimate forest extraction methods and biomass availability for renewable energy production. In: Proceedings of FOSS4G Conference, September 6–9, Barcelona, Spain.

Zimbalatti, G., Proto, A. R. 2007: Cable Logging opportunities for firewood in Calabrian forestry. In: Proceedings of FORMEC Conference, October 7–11, Vienna and Heiligenkreutz, Austria.

Zimbalatti, G., Proto, A. R., 2009: Cable logging opportunities for firewood in Calabrian forests. *Biosystems Engineering* 102(1): 63–68.

Zimbalatti, G., Proto, A. R., 2010: Timber extraction with a cable crane in South Italy (Calabria). In: Proceedings of FORMEC Conference, July 11–14, Padova, Italy.

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

Author's address – *Autorova adresa:*

Prof. Raffaele Cavalli, PhD.
e-mail: raffaele.cavalli@unipd.it
Forest Operation Management Unit
Department Land, Environment, Agriculture and
Forestry
University of Padova
Viale dell'Università 16
35020 Legnaro
ITALY

Received (*Primljeno*): August 2, 2012
Accepted (*Prihvaćeno*): September 14, 2012