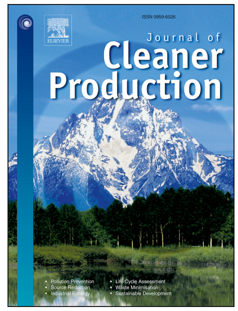


Is stump harvesting for bioenergy production socially acceptable in Finland?

Abul Rahman, Tahamina Khanam, Paavo Pelkonen

PII: S0959-6526(19)31563-X

DOI: https://doi.org/10.1016/j.jclepro.2019.05.045

Reference: JCLP 16810

To appear in: *Journal of Cleaner Production*

Received Date: 3 October 2018

Revised Date: 24 April 2019

Accepted Date: 5 May 2019

Please cite this article as: Rahman A, Khanam T, Pelkonen P, Is stump harvesting for bioenergy production socially acceptable in Finland?, *Journal of Cleaner Production* (2019), doi: https://doi.org/10.1016/j.jclepro.2019.05.045.

Is stump harvesting for bioenergy production socially acceptable in Finland?

Abul Rahman[a *], Tahamina Khanam[a,b], Paavo Pelkonen[a]

[a] School of Forest Sciences, University of Eastern Finland, PO Box 111, 80101 Joensuu, Finland

[b] Cambridge Judge Business School, University of Cambridge, EPRG, CB2 1AG, Cambridge, UK

***** Corresponding author. Present address: Yliopistokatu 7, Borealis building, P.O.Box 111, 80101 Joensuu, Finland. Phone: +358 44 05 21 229; E-mail: abul.rahman@uef.fi

Acknowledgement

The authors would like to thanks Fortum foundation (Grant number 201400229) and Finnish Cultural foundation (Grant Number 22356) for providing the financial support. The author also like to thank Urpo Hassinen, Juha Inka for helping questionnaire survey.

Is stump harvesting for bioenergy production socially acceptable in Finland?

Abstract

Stump wood is used to produce electricity and heat, especially in Finland, where biomass-based energy plays a major role. This study, which aims to investigate the social acceptance of stump harvesting for bioenergy production in Finland, was conducted in two stages: a questionnaire-based study and a subsequent literature-based study. The latter provides information concerning the beneficial or harmful consequences of stump harvesting, and this information could be used to gain support for stump harvesting's use or abandonment by stakeholders of forest utilization. The questionnaire survey was conducted in 2013 at the SILVA fair organised by the Association of Finnish Forestry centre in Joensuu, Finland, and the literature-based study was conducted in 2018. Six social groups were defined: higher administrative, lower administrative, skilled or specialized workers, farm and forestry workers, students, and others. The results of the questionnaire revealed that, although different social groups are highly interested in using stump wood for energy purposes, respondents think that stump harvesting will not be able to raise their incomes. Respondents are also unmotivated, with even forestry workers expressing critical views on the promotion of stump harvesting for energy purposes due to the environmental consequences. The literature-based study revealed that scientific results on stump harvesting are contradictory. It is crucial to involve different social groups and to reflect on their opinions regarding the use of stump wood as a forest management tool and for bioenergy production. As Finland moves toward a bioeconomy, the study of social acceptance of stump harvesting will direct the development of stump harvesting for bioenergy production.

Keywords

Bioenergy, Environment, Social acceptance, Social group

1. Introduction

Electricity is vital to improve people's standard of living around the world. There are now diverse technologies and new sources of energy to be utilized in electricity production. In order to avert the devastating effects of climate change, it is necessary to use cleaner technology in generating electricity. Bioenergy plays a role in securing energy, stimulating rural progress, and mitigating climate change (Acosta-Michlik et al., 2011). Woody biomass from forests has become an important source of bioenergy in many European countries, especially in Finland and Sweden. Using tree stumps for energy purposes is one of the interesting sources of bioenergy. Finland has remarkable forest resources, and logging residues together with wood wastes from wood-processing industries constitute the main source of bioenergy. Usually, slash and stump are used for burning in combined heat and power (CHP) plants to produce electricity. Because of the high calorific value of stump wood (Eriksson and Gustavsson, 2008), the production of bioenergy from stump would be attractive. UPM-Kymmene, a Finnish corporation, began using stump wood commercially for energy purposes in Finland in 2001 (Hakkila, 2004). Stump harvesting can increase wood fuel production, improve site preparation, and reduce root rot (*Heterobasidion*) (Walmsley and Godbold, 2009). On the other hand, several studies have shown the adverse effects of stump harvesting on the environment. Major adverse effects include future site productivity reduction, reduced physical structure of soil, and the immediate release of CO_2 into the atmosphere (Walmsley and Godbold, 2009; Moffat et al., 2011).

In Finland, about 60% of forestland is privately owned forests (FFA, 2017), and many stakeholders are involved in the stump harvesting process for bioenergy production. The forestry industry actually consumes a large number of stumps and processes them for CHP plants. Generally, private forest owners demand to attain extra income from stump harvesting. Forest owners also seek to attain a cost-effective process and technology for stump harvesting. On the other hand, Environmental Non-Governmental Organizations (ENGOs) publicly express concern about the effects of stump harvesting on forest biodiversity among other ecological matters (World Wildlife Fund [WWF], 2013). However, there is much discussion and research ongoing in Finland concerning stump harvesting due to its positive and negative impacts.

In the bioenergy sector, social acceptance is a prerequisite for the conversion of the energy sector from non-renewable to renewable energy (Dwivedi and Alavalapati, 2009). However, the public knows little about bioenergy compared to solar and wind energy (Segon et al., 2012). Social acceptance indicates the fact that a new issue is accepted, or tolerated, by a community. It is a significant issue in the attainment of a renewable energy policy target. Devine-Wright (2007) suggested that public support is essential for utilizing renewable energy technologies. Public opinions are a vital social factor in implementing any new idea (Assefa et al., 2007). Moreover, the social acceptance of bioenergy can increase the growth of the bioenergy market (Magar et al., 2011). In addition, Chin et al. (2014) recommended that neglecting social acceptance can limit biofuel development. There is little academic research on the social acceptance of bioenergy, but it is necessary in order to realize the stakeholders' views about this issue (Raven et al., 2010). Understanding the social acceptance of stump harvesting can contribute to knowledgeable scientific and policy discussions on the demand for stump wood in bioenergy production.

Finnish forest bioenergy mainly comes from forest residues such as slash, branches, and stumps; therefore, bioenergy production from forest resources requires increased forest logging. Numerous studies have investigated the productivity and environmental consequences of stump harvesting. However, no specific studies have yet focused on the social acceptance of stump harvesting; few have studied the social acceptance of bioenergy or wood-based biomass, but none have studied stump wood-based biomass. Social acceptance is vital for the introduction into the existing forest management system of any changes, whether partial or total, or a new management system. It is essential that researchers identify social reactions to stump harvesting and that policy makers become aware of what people desire in policy development and adaptation. Whether or not the broader society other than scholars, professionals, and policy makers accept the adoption of using stump wood for bioenergy production can become an obstacle to developing appropriate policies. Neglecting the issue of social acceptance could be an obstacle to adopting stump wood use for bioenergy purposes. The main aim of this research is to investigate how Finnish society accepts stump harvesting by both discussing the social acceptance of stump harvesting for bioenergy production and identifying the crucial factors that influence its acceptance. This study will provide updated information about what kind of scientific studies have been undertaken in the recent past to consider the significance of stump harvesting as a bioenergy source.

2. Material and methods

This paper is a combination of a report on a social group questionnaire survey conducted in North Karelia, Finland, and a review of existing scientific results on stump harvesting from 2000-2018. The questionnaire survey was conducted among different social groups in 2013, during the SILVA fair in Joensuu, Finland, an open public fair organized by different forestry organizations for people of all social groups in Finland. Thereafter, taking advantage of the survey findings, a separate study with a relevant literature review was carried out on public knowledge, perceptions, and attitudes regarding stump harvesting (see Rahman et al., 2017).

2.1 Questionnaire design

The questionnaire comprised 28 questions, including 5 regarding demographic information about each individual respondent. The remaining 23 questions assessed people's views on and acceptance of stump harvesting; 8 of these addressed the social acceptance of stump harvesting. Participants were categorized into six social groups following Näyhä (1977): 1) higher administrative or clerical employees and persons with academic degrees; 2) lower administrative or clerical employees; 3) skilled or specialized workers; 4) farm and forestry workers; 5) students and pupils; and 6) others (Table 1). Each respondent represented a particular social group and was asked about his or her own opinion, as well as questions related to socio-political acceptance (SPA), community acceptance (CA), and market acceptance (MA) of stump harvesting. In total, 166 questionnaires were selected for analysis out of 178 returned questionnaires.

<< Table 1 about here>>

The mixed format questionnaire (open-ended and closed-ended format) was first formulated in English; a Finnish translation was done by bioenergy experts for the final survey. Answers to the closed-ended questions were evaluated on a five-point Likert scale (1=Strongly agree, 2=Agree, 3=No opinion, 4=Disagree, and 5=Strongly disagree). Questions were then categorized into SPA, CA, and MA dimensions. To discern the significance of the results, they were grouped thus: Strongly agree + Agree = Accept, No opinion = No opinion, and Disagree + Strongly disagree = Reject. Before carrying out the final survey, a pilot survey had been conducted with 15 randomly selected respondents; thereafter, the final questionnaire was composed after considering their responses.

2.2 Theoretical and analytical framework of the questionnaire

Usually, there are three dimensions of social acceptance, as mentioned above: SPA, CA, and MA. SPA refers to the policies and technologies that are accepted by policy makers, stakeholders, and the public. CA refers to trust, and both procedural and distributional justice. Finally, MA refers to the facts that are accepted by the consumers, investors, and intra-firms. In the social acceptance discussion, we focused more on the positive outcomes of stump harvesting, as the social acceptance of a specific product mostly depends on its positive performance and not on negative outcomes. In Fig. 1, the social acceptance of stump harvesting is represented from the viewpoint of the general public. The utilisation of stump wood for bioenergy question was categorized in all social acceptance dimensions. The promotion of stump harvesting questions were categorized in SPA and CA dimensions. Economic and ecological questions were categorized in the MA dimension.

<< Figure 1 about here>>

2.3 Literature-based study

A comprehensive literature review was carried out in 2018. The data was collected by a web search of databases that indexed internationally peer-reviewed journals platform Science Direct, Taylor and Francis Group, etc. *Stump removal* and *stump harvesting* were the keywords used. The literature survey section of this study categorized research articles published since 2000 into two sections: scientifically accepted findings that directly or indirectly agree and those that directly or indirectly do not agree about stump harvesting. The literature review carried out in this study focused on the different challenges and obstacles to stump harvesting in the scientific and social environment. It also focused on the critical thinking skills of the past, ensuring that all socially acceptable issues were incorporated within the survey queries and represented there as possible consequences. Finally, the findings of the literature-based study were linked with the SPA, CA, and MA studies introduced by Wüstenhagen et al. (2007).

In addition, the study investigated the current situation of stump harvesting in Finland by collecting data form Finnish Natural Resources Institute (Luke) statistics. This type of composite study, comprising a comprehensive literature review combined with survey data, will help us attain an updated and timely understanding of the social acceptance of stump harvesting in contemporary Finland. In addition, the comparative meta-analysis-based study will help identify the gaps in previous studies and measure the efficiency of social acceptance.

3. Results and discussion

3.1 Social group opinions and socio-political acceptance

In the questionnaire, more than 30% of each social group's respondents indicated some sort of social acceptance and willingness to use stumps as a fuel (Fig. 2). Moreover, almost 50% of students and forestry workers showed the highest interest in stump bioenergy, compared with other social group respondents. On the other hand, interestingly, the majority of respondents did not accept that they wanted to promote stump harvesting, except for forestry workers whose opinions were equally divided between acceptance and non-acceptance. It seems that people from different social groups are still confused about stump harvesting. This indicates that there are various uncertainties in long-term policy support of stump harvesting.

<<Figure 2 about here>>

Bioenergy from forest resources is a low carbon footprint energy source that has attracted the attention of scientists and policy makers. Bioenergy contributes a major share of renewable energy in EU countries (Scarlat et al., 2015). Renewable energy has reached a 16% share of total energy consumption, and solid biomass contributes 82% to renewable heat production in the EU (EC Progress Report, 2018). The utilisation of renewable energy in the greenhouse heating system has become successful (Esen and Yuksel, 2013). It is projected that by 2020, bioenergy can contribute 45% of heat and electricity production in the field of renewable energy sources (Banja et al., 2013). Finnish bioenergy policy has emphasized industrial by-products, and Finland has a long history of getting bioenergy from its forests. In an independent society, public demand and opinion are vital factors influencing policy-making. McCormick (2007) suggested that SPA refers to how people react to government policies, propound solutions for conflicting matters, and make decisions. UPM-Kymmene Company is one of those corporations that is highly interested in adopting and developing stump harvesting technology (UPM, 2018). In Finland, before commercial harvesting of stumps was established, it was anticipated that it would bring in extra fuel wood for bioenergy, and it was also claimed that it would theoretically reduce pine weevil (*Hylobius abietis*) and root rot (*Heterobasidion*) damage, as these form colonies in stumps and roots. In our study, most higher administrative, skilled workers, and forest workers showed support for the use of stump harvesting to regulate pine weevil and root rot damage. In addition, the government has provided subsidies for stump harvesting (Walmsley and Godbold, 2009) and for energy generation (Hanna et al., 2017). On the other hand, World Wildlife Fund (WWF) Finland claimed that stump harvesting is a threat to biodiversity and the forest ecosystem. WWF also claimed that the practice of stump harvesting is a ‘Finnish Phenomenon’ that is not a sustainable practice for forestry (WWF, 2013).

3.2 Social group attitude and stakeholders’ acceptance

More than half of skilled workers rejected the idea of pushing politicians to promote stump harvesting; forestry workers were the exception and were again equally divided on this issue. It seems that people whose livelihoods depend on forestry are much more highly motivated to promote stump harvesting than are people of other social groups. Although different social groups have no interest in promoting stump harvesting, most nevertheless accepted that stump harvesting could increase fuel wood production. Most social groups, especially almost 70% of the higher administration group, rejected the proposition that stump harvesting could provide more revenue. In the case of forest management, especially preparation of regeneration sites, all social groups strongly agreed that stump harvesting has a vital role; more than 80% of higher administrative persons, skilled workers, and forestry workers accepted this view. Concerning forest pest management, all social groups, and in particular more than 70% forestry workers, strongly agreed that stump harvesting controls pine weevil (*Hylobius abietis*) damage and root rot (*Heterobasidion*). It seems that, in our study, most respondents accepted the opinion about stump harvesting, which reflects the MA dimension (Fig. 3). SPA and MA jointly got the highest priority among our respondents with regard to the stump harvesting issue.

<<Figure 3 about here>>

Finland might have good opportunities to develop new sources of forest bioenergy, for example, from short rotation trees and stump removal. However, the social acceptance of these sources is rather low. Our questionnaire showed that higher administrators, skilled workers, and students showed the least interest in pushing politicians to promote stump harvesting, although stump harvesting is allowed in Finland for bioenergy production with some guidelines (Koistinen, 2016). In general, government policies and support programs seem to be essential for bioenergy use

(Scarlat and Dallemand, 2011). The acceptance of stump harvesting by the media, ENGOs, forest companies, and the government is essential in the context of the socio-political development of acceptance. Our study revealed that different social groups highly appreciated stump harvesting because of its use in promoting forest health through site preparation and both pine weevil and root rot damage control.

3.3 Scientific acceptance of stump harvesting

It is to be understood that the different dimensions of social acceptance are not always confined within a single boundary. They might spread into other dimensions or might overlap with the other dimensions. This may be assessed variously, according to the researcher's judgments. Nevertheless, this study made an attempt to provide a coherent account of the corresponding dimensions of the stump harvesting social acceptance study (Table 2).

Regarding the MA dimension, it has been reported that stump wood chips have less moisture (Hakkila and Aarniala, 2004) and a quite uniform structure (Ala-fossi et al., 2007), which is important for market value. The survival rate of seedlings is quite prominent by stump and slash harvesting (Karlsson and Tamminen, 2013). For proper market management, harvested stump should be kept in a single pile rather than multiple piles (Rahman et al., 2015). On the other hand, several studies have provided negative supporting statements for stump harvesting in terms of the MA dimension. One important finding is that stump harvesting can delay the decomposition of coarse roots (Repo et al., 2015) and affect the growth of fungi, lichen, and moss species (Kubart et al., 2016).

Concerning the SPA dimension, it has been asserted that there is no significant difference in carbon balance after stump harvesting in the long run (Hyvönen et al., 2016). In addition, using stump wood instead of fossil fuel has environmental benefits (Ortiz et al., 2016). On the other hand, a previous study found that, in a short period, stump harvesting can affect soil carbon balance (Hope, 2007).

Further, regarding the CA dimension, stump harvesting has been reported to have economic and environmental benefits (Gonçalves da Costa et al., 2017). However, to increase competitiveness, stump needs a higher price than the current price (Walmsley and Godbold, 2009).

Overall, 31 scientific studies supported stump harvesting, while 27 studies did not support it. In the MA dimension, five scientific articles supported stump harvesting, while eight did not. In the SPA dimension, five scientific articles indicated a positive attitude toward stump harvesting and four articles represented a negative attitude. In addition, in the CA dimension, two articles showed a positive attitude, while no article represented a negative attitude. However, many of these articles examined more than one dimension together: market and community acceptance (MA + CA), market and socio-political acceptance (MA + SPA), community and socio-political acceptance (CA + SPA), or community, socio-political, and market acceptance (CA + SPA + MA). Most scientific articles explored MA and SPA dimensions together, of which, thirteen articles represented a positive attitude toward stump harvesting, while seventeen articles showed a negative attitude. Our study thus showed that scientific research results are diverse and even contradictory. As shown in Table 2, it seems that acceptance and rejection of stump harvesting is almost equally divided among the scientific community.

<<Table 2 about here>>

3.4 Status of stump harvesting

Several policy instruments support Finland's forest-based bioenergy (Makkonen et al., 2015). Because of such support, Finnish bioenergy production increased quickly in the past decades. Stump wood for bioenergy production has also become popular in recent years. However, stump harvesting is decreasing since 2013. In fact, stump removal has received much media attention in Finland. A national daily newspaper published an article which stated that it is a sin to burn stump (Helsingin Sanomat, 3 December 2010). In addition, stakeholders with sufficient knowledge have a critical view of stump harvesting (Rahman et al., 2017). Stakeholders' opinions can be different as per their interest, although they have access to the same scientific publications (Peters et al., 2015). In addition, the Programme for the Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC) have allowed stump extraction in Finland (PEFC, 2014; FSC, 2011). To ensure sustainable practice, Finland has established guidelines for stump harvesting (Koistinen et al., 2016).

Further, the use of commercial stump chips for CHP plants gradually rose until 2013 (Fig. 4). The highest recorded consumption of forest chips by Finnish CHP plants was in 2016, around 7.4 million solid cubic meters that included 0.8 million cubic meters stump wood chips (Luke Statistics, 2017).

Henrik (2014) mentioned that Stora-Enso closed their program to use stump wood for their bioenergy plant, and UPM-Kymmene Company decided to stop increasing the supply of stump wood, although they will continue burning stump wood for bioenergy production. This might be an indication of the poor market development of stump wood-based bioenergy observed during the last few years, especially after 2013. Innovators in the field need to identify new technologies for stump harvesting. Due to the poor market development, there is a lack of research interest in the technology development of stump harvesting.

<< Figure 4 about here>>

3.5 Community acceptance of stump harvesting for bioenergy production

CA refers to the acceptance of stump harvesting for bioenergy production by the local residents, local authorities, and other local stakeholders. Although numerous opinion-based studies have reported that public support exists for renewable energy production, many projects face local resistance during the implementation phase (Devine-Wright, 2009). The outcome of any project can be accepted by the community if there is fairness (Gross, 2007). It is also important that local people trust outside investors (Huijts et al., 2007). Mercer-Mapstone et al. (2018) studied the quality of company-community relationship with trust, acceptance, and fairness. In the case of stump harvesting, *stakeholder satisfaction* is a vital factor in gaining a continuous supply of stump wood. In our study, it was found that respondents of different social groups are still confused about the issue, and large-scale stump harvesting projects will most likely face obstacles. It seems that although communities are positive about stump harvesting, they are also concerned about environmental issues. Panoutsou (2008) supported the findings of our study, indicating that people usually are not against bioenergy but are influenced in their decision-making by environmental uncertainties. Many people do not want to demonstrate their views against bioenergy, in general, as it contributes to the mitigation of climate change. For instance, respondents in this study from an administration background showed less interest to promote stump harvesting. Recently, the *European Academies* suggested that the carbon stock of forests can be damaged by excessive forest energy production, and that in the area of sustainable bioenergy production, it is indispensable to consider forest carbon stocking (European Academies' Science Advisory Council [EASAC], 2017).

Moreover, Khanam et al. (2017) showed that experts on energy sector response believe that EU energy policy is not enough to reduce greenhouse gases.

According to Wright and Reid (2011), public opinion concerning bioenergy is influenced by the media. Thus, it is essential that the media provide a balanced account of both positive and negative features of stump harvesting and society's beliefs regarding it. Sometimes, less scientifically relevant issues become important in the media and society, and this can play a significant role in the bioenergy sector (ECN, 2008). It is critical that researchers provide Finnish society with scientifically demonstrated results about both the environmental consequences and the environmental benefits of stump harvesting. From a community's point of view, people are not completely against stump harvesting. They seem to expect more research on environmental issues and creative solutions of high-quality technology to increase stump harvesting. A poor readiness to promote stump harvesting indicates that different social groups are aware of the negative effects of stump harvesting.

3.6 Market acceptance of stump harvesting for bioenergy production

MA refers to the adoption of a new process or technology in a market. The MA of bioenergy from stumps is highly dependent on the performance of individual innovators and scientists, companies, and investors on one hand and on individual customer awareness and their adoption processes on the other. The MA of stump harvesting depends on consumer and producer acceptance. The technical advantage of stump harvesting is that stump wood has high-energy content (Eriksson and Gustavsson, 2008). Stump wood, however, contains many impurities that may affect combustion cylinders in CHP plants. Improved technologies for reducing the impurities of stump wood can increase the demand for stump harvesting.

People should be aware of and provided with relevant and understandable information and knowledge for enhancing acceptance to use a new bioenergy source. Contradictory and confusing research outcomes do not support any preconditions for changes of attitude. The willingness of corporations to invest in stump harvesting is significant for MA. Big forest companies can invest in stump harvesting if they find it profitable. The government's long-term subsidies have an important role to play in improving the stump-harvesting process and its social acceptance. A product can easily enter the market if consumers accept it widely (Van de Velde, 2009). A previous study in China showed that nuclear power plants gained social acceptance due to economic growth and market demand (Yuan et al., 2017). The media and NGOs have a pivotal role to play in spreading information throughout society to broaden the scope of public environmental concern.

The present study revealed that respondents of different social groups thought that stump harvesting can increase the production of wood fuel. In addition, our analysis of stump wood chip consumption data showed that consumption peaked in 2013, when our questionnaire survey was conducted. Thereafter, stump wood chip consumption declined for different factors, such as technological obstacles, contradictory scientific results, and confusion about stakeholders' social acceptance. When commercial stump harvesting began in the early 2000s, soil scarification was associated with stump harvesting (Karha, 2012). The combination of stump harvesting and soil scarification was not continued because of poorer planting spots (Rantala et al., 2010). The technology used by corporations in modern stump harvesting has dramatically improved, so it is possible to handle stumps of any diameter, and mobile crushers and forwarders with chippers have made it more profitable than before (NWH, 2007). Forest companies are investing more money into further improving stump harvesting techniques, which is in turn influencing forest owners to allow stump removal in clear-cut areas. Forest companies are significant stakeholders with respect to acceptance of stump harvesting. There is also an ongoing discussion that bioenergy should have 'satisfactory climate benefits' and that solid biomass should be included in sustainability criteria (EASAC, 2017). This discussion can influence the future industrial use of stump wood for energy.

4. Conclusion

The literature review-related findings of our study showed that scientific results are diverse and at times contradictory. Further, a sort of general finding from the questionnaire survey was that people are very much divided into pro- and against-stump harvesting groups. The current situation of stump harvesting is now in an unclear phase owing to different and contradictory scientific research results. This may influence the level of social acceptance of stump harvesting in Finland. As stump wood is a new source of bioenergy and there are multiple uncertainties regarding its continued use in the future, the social acceptance of stump harvesting has received only little attention from scholars. According to our survey and the literature reviewed above, overall, Finland is rather critical about stump harvesting. Acceptance varies clearly between and even within different social groups. This variation is one indicator showing that citizens need more relevant scientific information and knowledge to understand the complexity of biomass, and especially of the stump wood-based energy system. This study's focus, social acceptance, is not an obstacle to the practice of stump harvesting, but it certainly will help to understand people's views and future directions of stump harvesting in Finland.

Reference

Acosta-Michlik, L., Lucht, W., Bondeau, A., 2011. Integrated assessment of sustainability trade-offs and pathways for global bioenergy production: Framing a novel hybrid approach. Rene. Sust. Energ. Rev. 15, 2791–2809. https://doi.org/10.1016/j.rser.2011.02.011

Ågren, G.I., Hyvönen, R., Nilsson, T., 2007. Are Swedish forest soils sinks or sources for CO2-model analyses based on forest inventory data, Biogeochemistry 82, 217-227. https://doi.org/10.1007/s10533-007-9151-x.

Ala-Fossi, A., Ranta, T., Vartiamäki, T., Laitila, J., Jäppinen, E., 2007. Large-Scale Forest Fuel Supply Chain Based. http://jukuri.luke.fi/handle/10024/514004. (accessed 15 January 2018)

Allmér, J., 2005. Fungal Communities in Branch Litter of Norway Spruce: Dead Wood Dynamics, Species Detection and Substrate Preferences. Faculty of Natural Resources and Agricultural Sciences, Ph.D. thesis. Department of Forest Mycology and Pathology, Swedish University of Agricultural Sciences, Uppsala.

Asiegbu, F.O., Adomas, A., Stenlid J., 2005. Conifer root and butt rot caused by *Heterobasidion annosum* (Fr.) Bref.s.l . Mol. Plant Pathol. 6, 395 – 409, DOI: 10.1111/j.1364-3703.2005.00295.x.

Assefa, G., Frostell, B., 2007. Social sustainability and social acceptance in technology assessment: A case study of energy technologies. Technol Soc. 29, 63–78. https://doi.org/10.1016/j.techsoc.2006.10.007

Åström, M., Dynesius, M., Hylander, K., Nilsson, C., 2005. Effects of slash harvest on bryophytes and vascular plants in southern boreal forest clear-cuts. J. Appl. Ecol. 42, 1194 – 1202. https://doi.org/10.1111/j.1365-2664.2005.01087.x.

Banja, M., Scarlat, N., Monforti-Ferrario, F., Dallemand, J.F., 2013. Renewable energy progress in EU 27 (2005–2020). Joint Research Centre, Ispra, Italy. http://iet.jrc.ec.europa.eu/remea/sites/remea/files/re_progress_in_eu_27_2005-2020_online_final.pdf (Accessed 13 November 2017)

Bahadur Magar, S., Pelkonen, P., Tahvanainen, L., Toivonen, R., Toppinen, A., 2011. Growing trade of bioenergy in the EU: Public acceptability, policy harmonization, European standards and certification needs, Biomass and bioenergy 35, 3318-3327. https://doi.org/10.1016/j.biombioe.2010.10.012

Caruso, A., Rudolphi, J., Thor, G., 2008. Lichen species diversity and substrate amounts in young planted boreal forests: a comparison between slash and stumps of *Picea abies* Biol. Conserv. 141, 47 – 55. https://doi.org/10.1016/j.biocon.2007.08.021.

Caruso, A., Rudolphi, J., 2009. Influence of substrate age and quality on species diversity of lichens and bryophytes on stumps. The Bryologist. 112, 520-531. https://www.jstor.org/stable/25614869?seq=1#page_scan_tab_contents.

Chin H-C., Choong, W-W.,Alwi, S R W., Mohammeda, A H, 2014. Issues of social acceptance on biofuel development. J. Clean. Prod. 71: 30-39.

https://doi.org/10.1016/j.jclepro.2013.12.060

Cleary, M.R., Arhipova, N., Morrison, D.J., Thomsen, I.M., Sturrock, R.N, Vasaitis, R., Gaitnieks, T., Stenlid, J. 2013. Stump removal to control root disease in Canada and Scandinavia: A synthesis of results from long-term trials. For. Ecol. Manage 290, 5-14, https://doi.org/10.1016/j.foreco.2012.05.040.

Devine-Wright, P., 2007. Reconsidering public attitudes and public acceptance of renewable energy tech-nologies: a critical review, Research council energy program. http://geography.exeter.ac.uk/beyond_nimbyism/deliverables/bn_wp1_4.pdf (accessed 19 June 2018)

Dwivedi, P., Alavalapati JRR, 2009. Stakeholders' perceptions on forest biomass-based bioenergy development in the southern US. Energ Pol, 37, 1999–2007

EASAC, 2017. https://www.easac.eu/fileadmin/PDF_s/reports_statements/Forests/EASAC_Forests_web_complete.pdf. (accessed 15 January 2018).

EC, 2018. Progress Reports. https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports (Accessed 11 November 2017)

EC statement, 2017. Commisions welcomes agreement on key legislation to tackle climate change. http://europa.eu/rapid/press-release_STATEMENT-17-5286_en.htm (accessed 14 January 2018).

ECN, 2008. Factors influencing the societal acceptance of new energy technologies: Meta-analysis of recent European Projects, Energy research center of The Netherland & Create acceptance (accessed on 20th July 2018). http://www.ecn.nl/docs/library/report/2007/e07058.pdf.

Egnell, G., Hyvönen, R., Högbom, L., Johanson, T., Lundmark, T., Olsson, B., et al. 2007. Miljökonsekvenser av stubbskörd – en sammanställning av kunskap och kunskapsbehov, p. 1-154, ISSN 1403-1892.

Egnell, G., 2016. Effects of slash and stump harvesting after final felling on stand and site productivity in Scots pine and Norway spruce. For. Ecol. Manage. 371, 42–49. https://doi.org/10.1016/j.foreco.2016.03.006

Eisenbies, M.H., Burger, J.A., Aust, W.M., Patterson, S.C., 2005. Soil physical disturbance and logging residue effects on changes in soil productivity in five-year-old pine plantations Soil Sci. Soc. Am. J. 69, 1833–1843, DOI: 10.2136/sssaj2004.0334.

Eliasson, P., Svensson, M., Olsson, M., Ågren, G.I., 2013. Forest carbon balances at the landscape scale investigated with the Q model and the CoupModel – responses to intensified harvests For. Ecol. Manage. 290, 67–78, https://doi.org/10.1016/j.foreco.2012.09.007.

Eriksson, L.N., Gustavsson, L., 2008 Biofuels from stumps and small roundwood – costs and CO_2 benefits. Biomass Bioenergy. 32, 897 – 902. https://doi.org/10.1016/j.biombioe.2008.01.017

Esen M., Yuksel T., 2013. Experimental evaluation of using various renewable energy sources for heating a greenhouse. Energy and Buildings 65: 340–351.

FFA, 2017. https://www.smy.fi/en/forest-fi/forest-facts/finnish-forests-owned-by-finns/.(accessed 15 January 2018).

FSC Finland, 2011. Suomen FSC-standardi, [Finnish FSC-standard].

Gibbs, J.N., Greig, B.J.W., Pratt, J.E., 2002. Fomes root rot in Thetford Forest, East Anglia: past, present and future. Forestry. 75, 191 – 202. https://doi.org/10.1093/forestry/75.2.191

Gonçalves da Costa L., Paes J. B., Cintra de Jesus Junior W., Brocco V. F. and Furtado E. L, 2017. Potential of selected fungi for biological stump removal of *Eucalyptus* spp. For. Ecol. Manage. 402, 265-271. https://doi.org/10.1016/j.foreco.2017.07.054

Gross, C., 2007. Community perspectives of wind energy in Australia. The application of a justice and community fairness framework to increase social acceptance. Energy Policy 35 (5), 2727-2736, https://doi.org/10.1016/j.enpol.2006.12.013.

Hakkila, P., Aarniala, M., 2004.Stumps – an unutilised reserve. www.tekes.fi/eng/publications/kannotengl1.pdf (accessed 9 January 2018)

Hanna, A., Otto, B., Paloma, H., 2017. Stumbling on a stump? (accessed on 20th July 2018). https://www.sll.fi/mita-me-teemme/kohtuutalous/biotalous/biotalousbrief_ENG_netti.pdf.

Henrik, S., 2014. Kantojen nosto hiipui, (accessed on 18th June 2018). https://www.maaseuduntulevaisuus.fi/mets%C3%A4/kantojen-nosto-hiipui-1.75107 (In Finnish).

Hope, G.D., 2007. Changes in soil properties, tree growth, and nutrition over a period of 10 years after stump removal and scarification on moderately coarse soils in interior British Columbia For. Ecol. Manage. 242 (2/3) 625 – 635. https://doi.org/10.1016/j.foreco.2007.01.072.

Huijts, N.M.A., Midden, C.J.H., Meijnders, A.L., 2007. Public acceptance of carbon dioxide storage. Energ. Pol. 35 (5), 2780-2789, https://doi.org/10.1016/j.enpol.2006.12.007.

Hyvönen, R., Kaarakka, L., Leppälammi-Kujansuu, J., Olsson, B.A., Palviainen, M., Vegerfors, B., Helmisaari, H-S.,2016. Effects of stump harvesting on soil C and N stores and vegetation 8-13 years after clear-cutting. Forest Ecol Manage. 371, 23–32. https://doi.org/10.1016/j.foreco.2016.02.002.

Johnson, D.W., Curtis P.S., 2001. Effects of forest management on soil C and N storage: meta analysis. For. Ecol. Manage. 140, 227 – 238. https://doi.org/10.1016/S0378-1127(00)00282-6.

Jurevics, A., Peichl, M., Olsson, B.A., Strömgren, M., Egnell, G., 2016. Slash and stump harvest have no general impact on soil and tree biomass C pools after 32-39 years. For. Ecol. Manage. 371, 33–41. https://doi.org/10.1016/j.foreco.2016.01.008

Kaarakka L., Vaittinen J., Marjanen M., Hellsten S., Kukkola M., Saarsalmi A., Palviainen M., Helmisaari H.-S, 2018. Stump harvesting in Picea abies stands: Soil surface disturbance and biomass distribution of the harvested stumps and roots. For. Ecol. and Manage. 425,27-34.https://doi.org/10.1016/j.foreco.2018.05.032

Kardell, L., 2008. Stubbrytning och schaktning - Skogsenergiförsöken i Vindeln 1979-2004. Sveriges Lantbruksuniversitet, Institutionen för skoglig landskapsvård, Rapport 102, p. 126 (In Swedish), https://pub.epsilon.slu.se/9206/11/kardell_l_rapport_102_121112.pdf

Kärhä, K. 2012. Comparison of Two Stump-Lifting Heads in Final Felling Norway Spruce Stand Silva Fennica 46(4), 625-640, https://doi.org/10.14214/sf.915.

Karlsson, K., Tamminen, P., 2013. Long-term effects of stump harvesting on soil properties and tree growth in Scots pine and Norway spruce stands. Scand. J. For. Res. 28 (6),550-558. https://doi.org/10.1080/02827581.2013.805808.

Kataja-aho, S., Smolander, A., Fritze, H., Norrgård, S., Haimi J., 2012. Responses of soil carbon and nitrogen transformations to stump removal. Silva Fennica 46, 169-179, http://www.metla.fi/silvafennica/full/sf46/sf462169.pdf.

Khanam, T., Rahman, A., Mola-Yudego, B., Pelkonen P., Perez Y., Pykäläinen J., 2017. Achievable or unbelievable? Expert perceptions of the European Union targets for emissions, renewables, and efficiency. Energ. Res. Soc. Sci. 34 144-153. https://doi.org/10.1016/j.erss.2017.06.040

Koistinen, A., Luiro, J-P., Vanhatalo, K., (toim.) 2016. Metsänhoidon suositukset energiapuun korjuuseen, työopas. Tapion julkaisuja. (accessed on 20th May 2018). http://www.metsanhoitosuositukset.fi/wp-content/uploads/2017/05/Metsanhoidon_suositukset_energiapuun_korjuuseen_Tapio_2016_C.pdf.

Kubart, A., Vasaitis, R., Stenlid, J., Dahlberg, A., 2016. Fungal communities in Norway spruce stumps along a latitudinal gradient in Sweden. Forest Ecol Manage. 371, 50-58. https://doi.org/10.1016/j.foreco.2015.12.017.

Luke statistics, 2017. (accessed on 18th June 2018). http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__04%20Metsa__04%20Talous__10%20Puun%20energiakaytto/01_Laitos_ekaytto.px/table/tableViewLayout1/?rxid=9a0b5502-10d0-4f84-8ac5-aef44ea17fda

Makkonen, M., Huttunen, S., Primmer, E., Repo., Hildén, M., 2015. Policy coherence in climate change mitigation: an ecosystem service approach to forests as carbon sinks and bioenergy sources. For. Pol. Econ, 50,153–162. https://doi.org/10.1016/j.forpol.2014.09.003

McCormick, 2007. Advancing Bioenergy in Europe: Exploring bioenergy systems and socio-political issues, (accessed on 20th July 2018). http://lup.lub.lu.se/search/ws/files/4511148/3731942.pdf.

Melin, Y., Petersson, H., Nordfjell, T., 2009. Decomposition of stump and root systems of Norway spruce in Sweden – A modelling approach For. Ecol. Manage. 257, 1445–1451, https://doi.org/10.1016/j.foreco.2008.12.020.

Mercer-Mapstone, L, Rifkin, W.,Louis W R., Moffat, K, 2018 . Company-community dialogue builds relationships, fairness, and trust leading to social acceptance of Australian mining developments. J. Clean. Prod 184, 671 – 677. https://doi.org/10.1016/j.jclepro.2018.02.291

Metla (The Finnish Forest Research Institute), 2008. Effect of stump harvesting on forest damages and saproxylic species. Metla Proj. 3478, 2007 – 2011. www.metla.fi/hanke/3478/index-en.htm. (accessed on 11 January, 2018)

Mjöfors, K., Strömgren, M., Nohrstedt, H.-Ö., Gärdenäs, A. 2015. Impact of site-preparation on soil-surface CO2 fluxes and litter decomposition in a clear-cut in Sweden. Silva Fennica 49, http://dx.doi.org/10.14214/sf.1403.

Moffat, A., Nisbet, T., Nicoll, B., 2011. Environmental effects of stump and root harvesting, Research note. https://www.forestry.gov.uk/pdf/FCRN009.pdf/$file/FCRN009.pdf (accessed 19 June 2018)

National Energy and Climate Strategy, 2016. Ministry of Economic Affairs and Employment, Finland. http://tem.fi/en/energy (accessed 20 January 2018).

Näyhä, S., 1977. Social group and mortality in Finland. Br. J. Prev. Soc. Med. 31, 231-237, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC479033/.

Northern woodheat, 2007. (accessed on 18th June 2018). http://www.karelia.fi/bioenergia/nwh/woodfuel_supply_chains/forest_chips/stumps.htm.

Ortiz, C.A., Hammar, T., Ahlgren, S., Hansson, P.-A., Stendahl, J., 2016. Time-dependent global warming impact of tree stump bioenergy in Sweden. For. Ecol. Manage. 371, 5-14. https://doi.org/10.1016/j.foreco.2016.02.014.

Paananen, S., Kalliola, T., 2003. Procurement of Forest Chips at UPM Kymenne from Residual Biomass (accessed on 23 March 2012). www.opet-chp.net/ download/wp3/upm_forestwood.pdf.

Panoutsou, C., 2008. Bioenergy in Greece: Policies, diffusion framework and stakeholder interactions. Energ Pol 36, 3674– 3685, https://doi.org/10.1016/j.enpol.2008.06.012.

PEFC. Finland, 2014. PEFC-metsäsertifioinnin Kriteerit,. [Criteria for PECF certification]. (accessed on 20th March 2019). http://pefc.fi/wp-content/uploads/2016/09/PEFC_FI_1002_2014_Metsaesertifoinnin_kriteerit_20141027.pdf

Persson, T., Lenoir, L., Vegerfors, B., 2013. Which macroarthropods prefer tree stumps over soil and litter substrates? For. Ecol. Manage. 290, 30-39. https://doi.org/10.1016/j.foreco.2012.09.009.

Persson, T., Lenoir, L., Vegerfors, B. 2017. Long-term effects of stump harvesting and site preparation on pools and fluxes of soil carbon and nitrogen in central Sweden, Scand. J. For. Res. 32(2017), p. 222-229, https://doi.org/10.1080/02827581.2016.1218043.

Peters D.M., Wirth, K., Böhr, B., Ferranti, F., Grriz-Mifsud, E., Kärkkäinen,L., Krc, J., Kurttila, M., Leban,V., Lindstad,B.H., Malovrh, S.P., Pistorius, T., Rhodius,R., Solberg, B., Stim, L.Z., 2015. Energy wood from forests—stakeholder perceptions in five European countries. Energy, Sustain Soc, 5,17. https://doi.org/10.1186/s13705-015-0045-9

Polomski, J., Kuhn, N., 2001. Root architecture and wind stability of trees, (Wurzelhabitus und Standfestigkeit der Waldbäume), Forstwissenschaftliches Centralblatt 120, p. 303 – 317, https://link.springer.com/article/10.1007/BF02796102.

Rahman, A., Viiri, H., Pelkonen, P., Khanam, T., 2015. Have stump piles any effect on the pine weevil (Hylobiusabietis L.) incidence and seedling damage? Global Ecol and Cons. 3,424–432. https://doi.org/10.1016/j.gecco.2015.01.012.

Rahman, A., Khanam, T., Pelkonen, P., 2017. People's knowledge, perceptions, and attitudes towards stump harvesting for bioenergy production in Finland. Rene. Sust. Energ. Rev. 70,107–116. https://doi.org/10.1016/j.rser.2016.11.228.

Rahman, A., Viiri, H., Tikkanen, O-P., 2018. Is stump removal for bioenergy production effective in reducing pine weevil (*Hylobius abietis*) and *Hylastes* spp. breeding and feeding activities at regeneration sites? Forest Ecol and Manage. 424, 184-190. https://doi.org/10.1016/j.foreco.2018.05.003

Ranlund Å.,Victorsson J, 2018. Stump extraction in the surrounding landscape: Predatory saproxylic beetles are more negatively affected than lower trophic levels. For. Ecol. and Manage 408,75-86. https://doi.org/10.1016/j.foreco.2017.10.030

Rantala, J., Saarinen, V.M., Hallongren, H. 2010. Quality, productivity and costs of spot mounding after slash and stump removal. Scand. J. For. Res. 25(6), 507-514, https://doi.org/10.1080/02827581.2010.522591.

Repo, A., Tuovinen, J.P., Liski, J., 2015. Can we produce carbon and climate neutral forest bioenergy? Global Change Biol. Bioenerg. 7, 253-262, https://doi.org/10.1111/gcbb.12134

Rosenberg, O., Jacobson, S., 2004. Effects of repeated slash removal in thinned stands on soil chemistry and understorey vegetation. Silva Fenn. 38, 133 – 142, DOI: 10.14214/sf.423.

Saarinen, V.-M., 2006. The effects of slash and stump removal on productivity and quality of forest regeneration operations – preliminary results, Biomass Bioenergy. 30, 349 – 356. https://doi.org/10.1016/j.biombioe.2005.07.014.

Saksa, T., 2012. Regeneration after stump harvesting in southern Finland. For. Ecol. Manag. 290, 79–82. https://doi.org/10.1016/j.foreco.2012.08.014

Scarlat, N., Dallemand, J.F., 2011, Recent developments of biofuels/bioenergy sustainability certification: a global overview. Renew. Sustain. Energy Rev. 39 (3), 1630-1646, https://doi.org/10.1016/j.enpol.2010.12.039.

Scarlat, N., Dallemand, J-F., Monforti-Ferrario, F., Banja, M., Motola, V., 2015. Renewable energy policy framework and bioenergy contribution in the European Union – An overview from National Renewable Energy Action Plans and Progress Reports. Rene. Sust. Energ. Rev. 51, 969-985. https://doi.org/10.1016/j.rser.2015.06.062

Segon,V., Støer, D., Domac,J .,Yang,K, 2004 . Raising the awareness of bioenergy benefits: results of two public surveys on attitudes, perceptions and knowledge. IEA Bioenergy/Task, 29, pp. 1-4

Strömgren, M., Hedwall, P.-O., Olsson, B.A., 2016. Effects of stump harvest and site preparation on N2O and CH4 emissions from boreal forest soils after clear-cutting. For. Ecol. and Manage. 371, 15-22. https://doi.org/10.1016/j.foreco.2016.03.019.

Svensson, M., 2013. Occurrence patterns of dead wood and wood-dependent lichens in managed boreal forest landscapes. Acta Universitatis Agriculturae Sueciae. Faculty of Natural Resources and Agricultural Sciences. Doctoral Thesis No. 2013:84.

Taylor, A.R., Victorsson, J., 2016. Short-term effects of stump harvesting on millipedes and centipedes on coniferous tree stumps. For. Ecol. and Manage. 371, 67-74. https://doi.org/10.1016/j.foreco.2016.03.039.

Thor, M., 2002. Stump treatment against root rot – European survey. Skog Forsk Report No.1. (accessed on 1 April, 2009), www.skogforsk.se/upload/Dokument/Results/2002-01.pdf.

UPM, Stump harvesting for energy, 2018. Translate from Finnish language (accessed on 21th July 2018). https://www.upmmetsa.fi/tietoa-ja-tapahtumia/videoartikkelit/kantojen-korjuu-energiaksi/.

UNFCC, 2016. Adoption of the Paris agreement. https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf (Accessed 11 November 2017)

Uri V., Aosaar J., Varik M., Becker H., Kukumägi M., Ligi K., Pärn L. and Kanal A, 2015. Biomass resource and environmental effects of Norway spruce (*Picea abies*) stump harvesting: An Estonian case study. For. Ecol. Manage. 335, 207-215. https://doi.org/10.1016/j.foreco.2014.10.003

VandeVelde, L., Verbeke, W., Popp, M., Buysse, J., Van Huylenbroeck, G., 2009. Perceived importance of fuel characteristics and its match with consumer beliefs about biofuels in Belgium Energ. Pol. 37(8), 3183-3193. https://doi.org/10.1016/j.enpol.2009.04.022.

Vasaitis, R., Stenlid, J., Thomsen, I.M., Barklund, P., Dahlberg, A., 2008. Stump removal to control root rot in forest stands. A literature study. Silva Fennica 42(3), 457–483, https://www.cabdirect.org/cabdirect/abstract/20083198333.

Wallertz, K., Nordlander, G., Örlander, G., 2006, Feeding on roots in the humus layer by adult pine weevil, *Hylobius abietis*. Agric. For. Entomol. 8, 273 – 279, https://doi.org/10.1111/j.1461-9563.2006.00306.x.

Walmsley, J.D., Godbold, D. L.,2009.Stump harvesting for bioenergy - A review of the environmental impacts. Forestry. 83, 17–38. https://doi.org/10.1093/forestry/cpp028.

Wright, W., Reid, T., 2011. Green dreams or pipe dreams? Media framing of the US biofuels movement. Biomass Bioenergy 35 (4), 1390-1399, https://doi.org/10.1016/j.biombioe.2010.07.020.

Wüstenhagen, R., Wolsink, M., Bürer, M.J. 2007. Social acceptance of renewable energy innovation: An introduction to the concept. Energ. Pol. 35, 2683-2691. https://doi.org/10.1016/j.enpol.2006.12.001.

WWF, 2013. https://wwf.fi/wwf-suomi/viestinta/uutiset-ja-tiedotteet/Kannonnosto-ei-kuulu-kestavaan-metsatalouteen-1935.a. (accessed on 20th July 2018)

Yuan, X., Zuo, J., Ma, R., Wang,Y, 2017. How would social acceptance affect nuclear power development? A study from China. J. Clean. Prod, 163, 179–186. https://doi.org/10.1016/j.jclepro.2015.04.049

Zabowski, D., Chambreau, D., Rotramel, N., Thies, W.G., 2008. Long-term effects of stump removal to control root rot on forest soil bulk density, soil carbon and nitrogen content. For. Ecol. Manage 255, 720 – 727. https://doi.org/10.1016/j.foreco.2007.09.046.

Table 1

Respondents of different social group (%)

Social group	Gender			Forest owners			Total Respondents (%)
	Male (%)	Female (%)	Total (%)	Own (%)	Not own (%)	Total (%)	
Higher administrative	49	51	100	66	34	100	32
Lower administrative	54	46	100	75	25	100	7
Skilled or specialized workers	35	65	100	74	26	100	19
Farm and forestry workers	24	76	100	88	12	100	15
Students and pupils	69	31	100	25	75	100	10
Others	57	43	100	69	31	100	17
Total							100

Table 2

Summary table of the literature review on social acceptance of stump harvesting.

Dimensions	**Supporting statements and references**	**Non-supporting statements and references**
MA	Dried stump has low moisture content, that leads to high storage life (Hakkila and Aarniala, 2004)	The positive environmental immediate consequence of stump harvesting may deferred as the coarse roots are decomposed slowly (Ågren et al. 2007; Repo et al. 2015)
	Stump chips are more uniform than other type of forest chips (Ala-fossi et al. 2007)	
	The seedling survival of Scots pine and Norway spruce was higher compared in slash and stump harvest compared to only slash harvest (Karlsson and Tamminen, 2013)	The seedling survival of Scots pine and Norway spruce has no big difference compared in slash and stump harvest compared to only slash harvest (Saksa, 2013; Egnell, 2016)
	If harvested stumps are stored in a large pile rather than scattered, it may decrease the pine weevil (*Hylobius abietis*) seedling damage (Rahman et al. 2015) Stump harvesting reduce pine weevil larvae and breeding resources (Rahman et al. 2018)	Stump harvesting create difficulties for the growth and survival of the fungi, lichens and moss species as their growth depend on the increasing of stump age (Caruso and Rudolphi 2009; Svensson, 2013; Persson et al. 2013; Kubart et al. 2016)
SPA	Study after 8-13 and 32-39 years revealed no substantial carbon differences between the stumps removed or retained stands (Hyvönen et al. 2016; Jurevics et al. 2016) Stump removal of Norway spruce did not cause soil nutrient and carbon loss significantly (Uri et al. 2015)	Study after 10 years of harvesting found the declining of soil carbon stocks (Hope, 2007)
	It favours the flora species that can survive in the wide disrupted soil structure (Åström et al. 2005) Environmental benefit is achieved instantly when stump using to replace fossil fuel (Ortiz et al. 2016)	Stump harvesting reduces the significant lichen species, unique or uncommon habitats and detriment effect on the deadwood habitat (Caruso et al. 2008) Stump harvesting negatively affect the deadwood-dependent species of the landscape (Ranlund and Victorsson, 2018)

CA	It leads to a source of fuel and income for the forest owners (Saarinen 2006) Stump harvesting represents economic and environmental potential (Gonçalves da Costa et al. 2017)	
MA+CA	Dried stump has high calorific value (Eriksson and Gustavsson 2008)	Stumps need higher prices to be competitive on the bioenergy market (Walmsley and Godbold 2009)
MA+SPA	After stump harvesting, soil disturbance intensify the net N mineralization and reduce green-house gases emissions (Persson et al 2017.)	Soil disturbance decreases the decomposition ratio of the organic matter (Strömgren et al. 2016)
	Compared with non-harvested plots 50% Millipedes decreased in stump-harvested stands (Taylor and Victorsson, 2016).	Stump harvesting effects are severe on the fungi that hosts by stump (Allmér, 2005)
	In coniferous species, 6% soil carbon declines and 8% increase due to trees (stem+branches+top) and stem only harvesting (Johnson and Curtis 2001)	In nutrient-poor soils sites, it leads to reduce soil carbon amount and negatively impacts on the soils (Hope 2007; Zabowski et al.2008; Melin et al. 2009; Eliasson et al. 2013; Mjöfors et al. 2015; Kaarakka et al. 2018)
	leads to increases the quantity of soil mineral (Kardell 2008; Kataja-Aho et al. 2012)	SH substantially disrupt the soil structure and reduce soil nutrient stocks (Eisenbies et al. 2005; Egnell et al. 2007; Kaarakka et al. 2018)
	Stump removal leads to efficiency gains in the site preparation since the site does not need any chemicals to reduce the soil diseases (Asiegbu et al. 2005; Saarinen 2006)	It cannot be the sole technique to pest control as the infested roots may remain in the soil, even after harvesting and infect the new plantations (Wallertz et al. 2006)
	It has potential to lessen root rot damage in the new plantations (Vasaitis et al. 2008; Cleary et al. 2013)	Stumps uprooting might enhance pine weevil infestation that accelerates seedling mortality (Metla, 2008)
	Harvesting of whole-tree reduces soil acidification (Rosenberg and Jacobson 2004)	Soil compaction have a greater negative influence than acidification on the root stability and tree growth (Polomski and Kuhn 2001)
	It favours the growth of natural regeneration plants like pine and birch (Karlsson and Tamminen 2013; Saksa 2013; Egnell 2016)	It disfavours the growth of secondary type species like spruce (Karlsson and Tamminen 2013; Saksa 2013; Egnell 2016)
CA+SPA	Many countries (e.g. Finland, Sweden, France, and Poland are using) are practicing as pests and diseases control method especially for *H. annosum* infestations (Gibbs et al. 2002; Thor 2002; Paananen and Kalliola 2003; Saarinen 2006)	
CA+SPA+MA	Stump harvesting has no negative consequence on the development of	

	the new plantations (Egnell et al. 2007)	
	It results to increase forest growth (Jurevics et al. 2016)	

MA=Market acceptance; SPA= Socio-political acceptance; CA= Community acceptance; MA+SPA= Market + Socio-political acceptance; CA+SPA= Community acceptance+ Socio-political acceptance; CA+MA= Community acceptance+ Market acceptance and CA+SPA+MA= Community acceptance+ Socio-political acceptance+ Market acceptance

CA= Community acceptance; SPA= Socio-political acceptance;
MA= Market acceptance

I would like to-
1. Use fuels from stumps
2. Promote stump harvesting to friends and family members or in a public hearing (like seminar)
3. Push politician to promote stump harvesting

I think-
4. It increase production of wood fuel
5. Forest owners earn revenue from stump energy
6. Stump harvesting improve site preparation
7. Stump removal reduce pine weevil insect damage to seedlings
8. Stump removal reduce root rot diseases

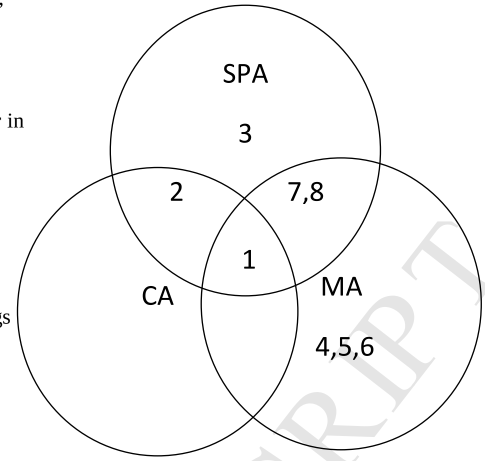
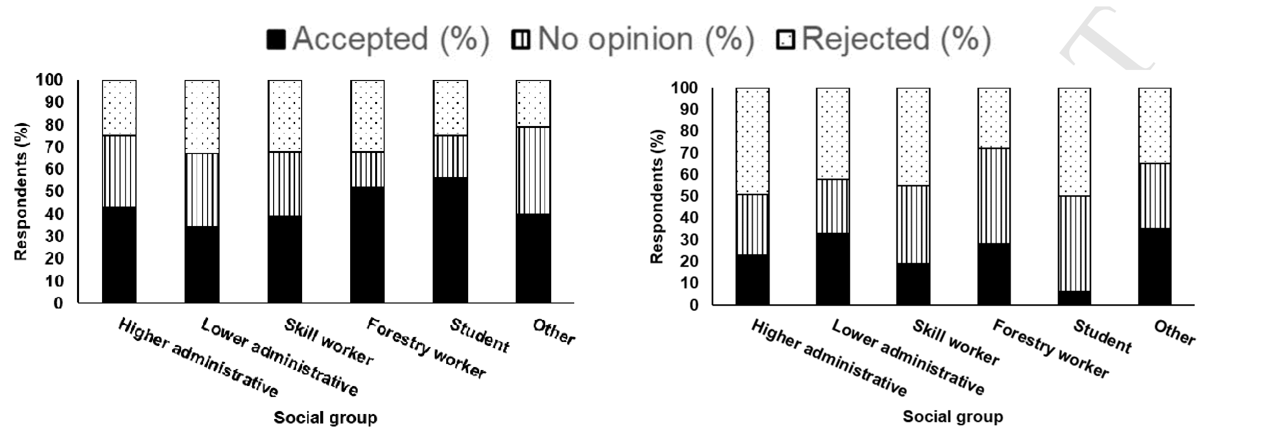
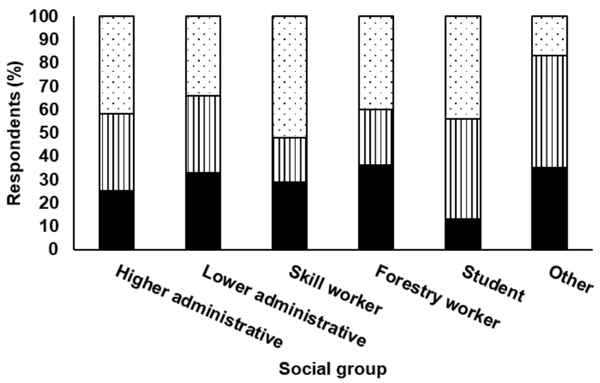


Fig. 1. Social acceptance of energy production from stump harvesting

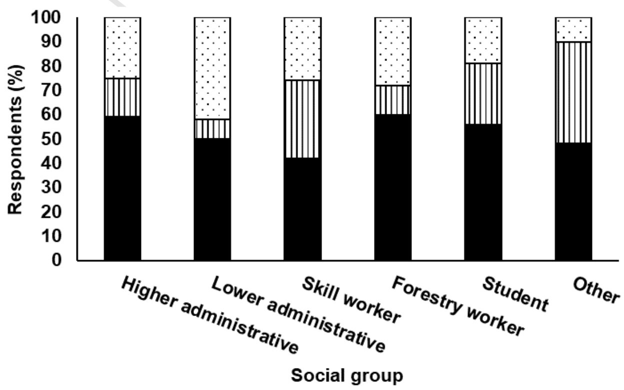


a. Use fuels from stumps(SPA, CA, MA)

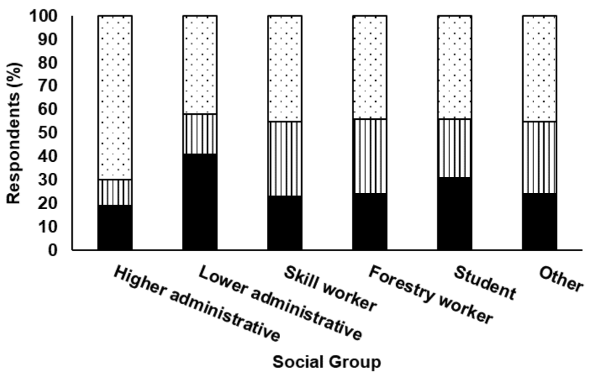
b. Promote stump harvesting (SPA, CA)



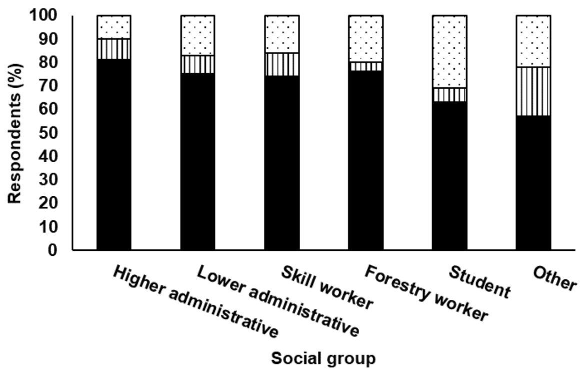
c. Push politician to promote stump harvesting(SPA)



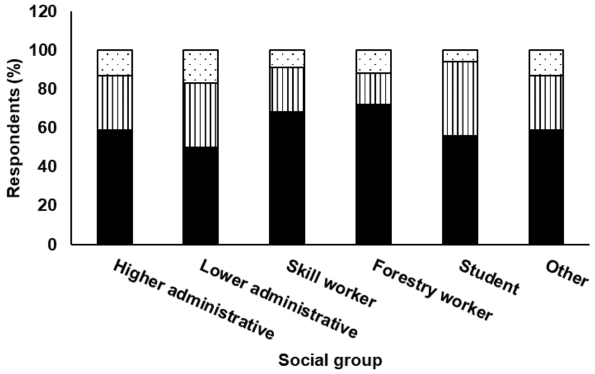
d. It increase production of wood fuel(MA)



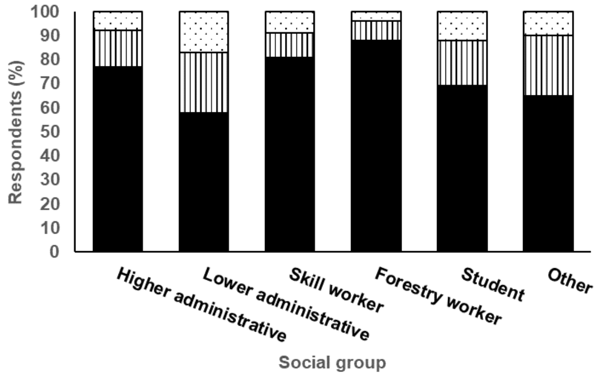
e. It earn revenue (MA)



f. Stump harvesting improve site preparation(MA)



g. It reduce pine weevil insect damage to seedlings (SPA, MA)



h. Stump removal reduce root rot diseases (SPA, MA)

Fig. 2. People's opinion of stump harvesting by different social groups

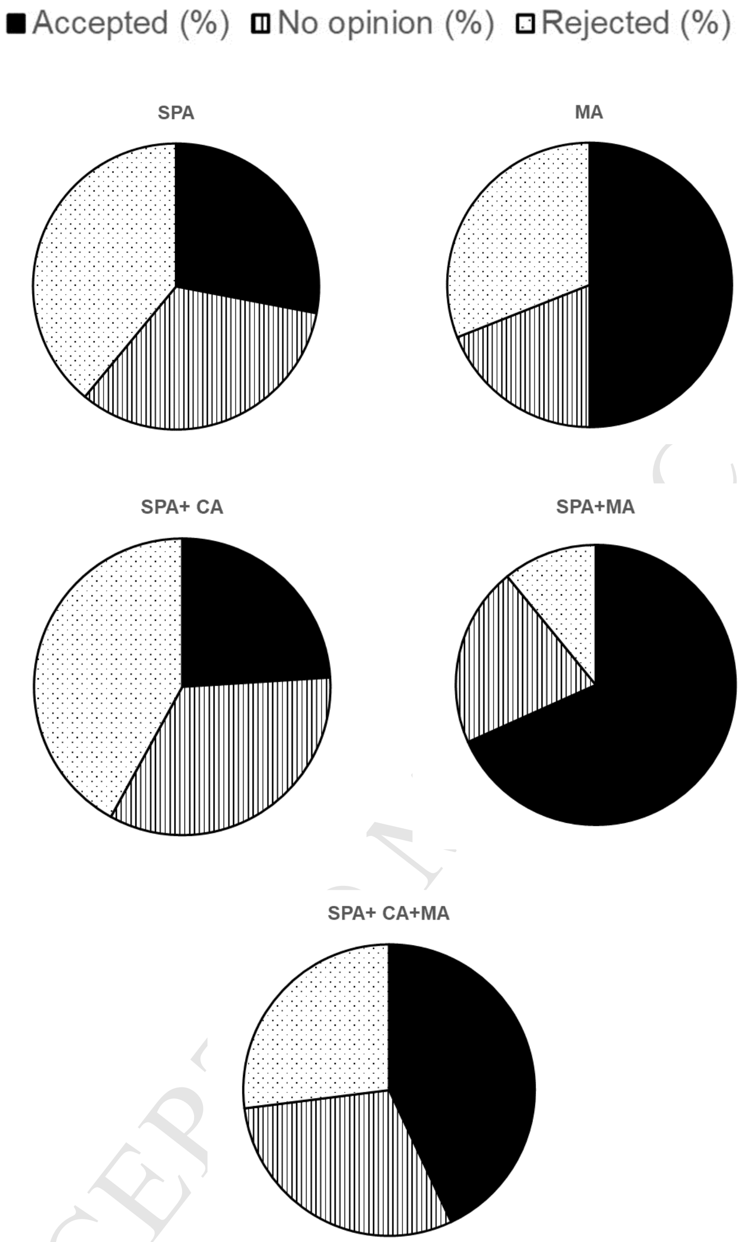


Fig. 3. Respondents' opinion percentages in the context of social acceptances dimensions.

MA=Market acceptance; SPA= Socio-political acceptance; CA= Community acceptance; MA+SPA= Market + Socio-political acceptance; CA+SPA= Community acceptance+Socio-political acceptance; CA+MA=Community acceptance+Market acceptance; and CA+SPA+MA=Community acceptance+Socio-political acceptance+Market acceptance

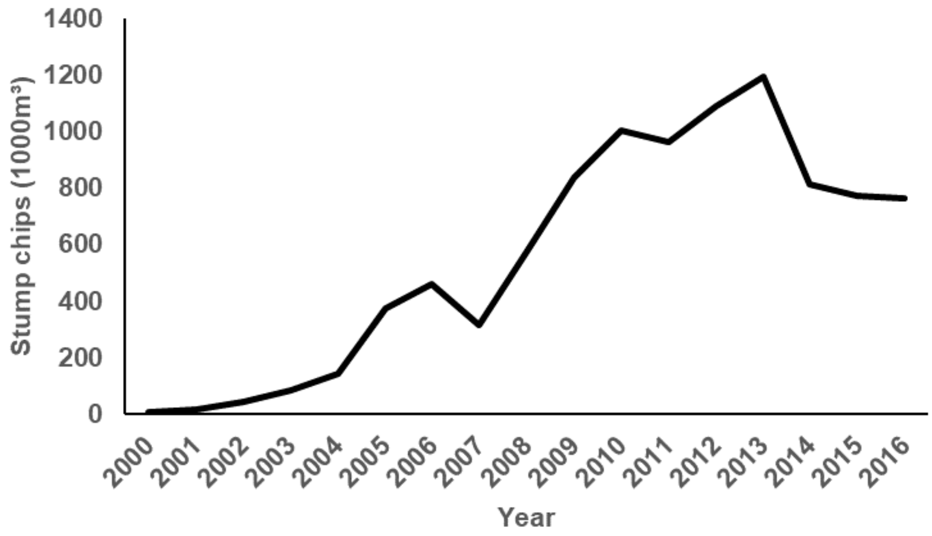


Fig. 4. Stumps chips consumption in heating and power plant in Finland (source – LUKE statistics 2017)