

Forecasting Future Global Timber Harvesting Requirements Using the Delphi Technique

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ABSTRACT - This paper gives an overview of the global future trends in timber harvesting. These trends were established by using the Delphi technique, a technique that is well suited to the long-term forecasting of technology orientated industries, such as timber harvesting. The technique was applied by using a panel of 15 experts from eight different countries. Questions addressed included trends in past and future change drivers, the position of harvesting systems in 2010, the future status of contractors and the requirements of a harvesting forester and a harvesting contractor in 2010. The results indicate that change in timber harvesting systems over the next decade will firstly be driven by environmental factors and secondly by technology/productivity improvements. There will be an increase in the outsourcing of harvesting operations and the size of contracts is expected to increase. The two most important attributes required in harvesting foresters and harvesting contractors are the ability to conduct sound harvesting planning and a thorough knowledge of the supply chain (from stump to mill). Interpersonal skills, management skills and business skills are also viewed as critical attributes in 2010.

INTRODUCTION

Considering the strong trend towards globalisation, it is essential to establish global trends, which will affect the future timber harvesting environment. These trends lie in identifying the change drivers over the next 10 years. The Delphi Technique was used to identify the relevant change drivers in timber harvesting as well as other issues that will affect operations in 2010.

The Delphi technique is a widely used method for achieving a structured anonymous interaction between carefully selected experts by means of a questionnaire with controlled feedback. Delphi was developed to specifically overcome the shortcomings of face-to-face meetings (Twiss, 1992). This technique is often used for a technological forecast (Adam and Ebert 1978). The Delphi is of most value in making long-term forecasts (Twiss, 1992).

The objectives of the type of forecast where Delphi is used are one of the following:

- to set normative targets;
- to identify new factors influencing the future state of technological developments or new needs which might be satisfied;
- to determine the commencement and shape of the S-curve of a new technology; and
- to establish the feasibility of a development under stated conditions.

The stages of the Delphi are:

- Appointment of an administrator, who is usually also the forecaster himself.
- Preparation of a draft questionnaire.
- Selection of experts.
- Validation of the questionnaire.
- Circulation of the questionnaire to the experts (Round 1).
- Analysis of Round 1 results and return to experts (Round 2).
- Analysis of Round 2 and return to experts (Round 3).
- Analysis of Round 3 results and preparation of the final forecast.

(Adam and Ebert, 1978).

The number of experts to be involved is dependant upon the nature of the problems being investigated. The administrative burden of selecting the right experts must not be underestimated. It is far better to have a small focused study involving high calibre participants than a large effort of poor quality. For most Delphi's, 15 to 40 participants is normal, with 25 being the most desirable. It does not necessarily purport an accurate prediction of the future, but rather gives guidance in its development (Twiss, 1992).

The Forest Engineering value chain refers to a portion of the forestry value chain. It includes the sequence of activities required to convert a standing tree into a marketable product and the delivery thereof to the primary processor. The Forest Engineering value chain consists of the following activities in the forestry environment:

- felling of standing trees
- debranching of felled trees
- cross-cutting or merchandising of tree lengths into a marketable product
- loading of products onto a truck to transport the commodity to a mill or factory
- transporting of the commodity
- unloading the commodity at the customer
- the value chain could also include the debarking of logs and/or the chipping thereof for the production of pulp.

The sequence of activities are not always the same and the unique combination of activities create the synergy in the value chain to use the most cost effective overall system to produce logs or chips.

The Delphi technique is the ideal method to identify the future change drivers that will impact on the Forest Engineering value chain. These forecasts are generally of a long-term nature, which is well suited to the Delphi technique. This technique is significantly more objective than expert judgment, where an individual or group of individuals have not gone through a structured process, such as used in a Delphi study.

USING THE DELPHI TECHNIQUE TO FORECAST TIMBER HARVESTING REQUIREMENTS

In order to gain the most effective and relevant information possible, countries were selected which will have the greatest influence on timber harvesting in the future. Three criteria used in the selection process were:

- current producers of harvesting technology (machinery and equipment);
- potential future producers of harvesting technology; and
- countries that have expanded, or are currently expanding their plantation forestry areas.

Table 1 gives information on the countries included, as well as prominent machine manufacturer brands in each of these countries.

Table 1: Countries included in the Delphi study

Country	Hemisphere	Industrial Annual cut * '000 (m ³)	Prominent machine brands produced
USA	Northern	406 595	John Deere, Timbco, Caterpillar, Prentice, Hydro Ax
Canada	Northern	183 113	Timberjack, Tigercat
Sweden	Northern	52 600	Timberjack, Loglift, Husqvarna
Finland	Northern	42 503	Cranab, Valmet
Germany	Northern	35 543	Stihl
New Zealand	Southern	17 000	Waratah
Australia	Southern	19 813	Rosin
Chile	Southern	21 387	
Total		778 554	

*Source: F.A.O (1999)

A significant sample of the total global industrial roundwood production was included in the study. Of the 1,49 billion cubic metres of industrial roundwood produced annually, the study included 778 554 000m³. This is over 52% of the global annual industrial roundwood production.

Panel members were carefully selected based on their International standing in Forest Engineering and specific knowledge of the particular region/country.

Due to the size and complexity of the USA and Canada, these two countries were divided into six and three regions respectively. Each of the other countries were treated as a single entity, with one panel member representing each country, except Chile, which had two panel members, of whom one completed the study. Table 3 below summarises the profile of the panel members:

Table 3: Profile of panel members

Region/Country	Panel member	Institution
USA: Pacific Northwest	Prof. L. Kellogg	Oregon State University
USA: Inland West Coast	Prof. L. Johnson	University of Idaho
USA: Lake States	Dr. C. Blinn	University of Minnesota
USA: South	Dr. D. Green	University of Georgia
USA: New England	Prof. C. Davis	SUNY
USA: Appalachian region	Dr. R. Visser	Virginia Tech
Canada: West Coast	Mr. A. Sauder	FERIC, Canada
Canada: Central	Prof. R. Pulkki	Lakehead University
Canada: East Coast	Prof. P. Zundell	University of New Brunswick
Sweden	Prof. J. Fryk	Skogforsk
Finland	Prof. E. Mikkonen	University of Helsinki
Germany	Prof. P. Warkotsch	University of Munich
New Zealand	Dr. G. Murphy	Forest Research
Australia	Mr. S. Shackleton	Timberjack
Chile	Mrs. V. Gonzalez	Universidad Mayor, Santiago

Three rounds of questionnaires were circulated to panel members in the selected countries.

The initial questionnaire was drawn up with consideration given to the guidelines of Trochim (1999) with regard to question design. Due to the difficulty in identifying all the relevant criteria, this questionnaire was used to expand the criteria that could be important in the forecast. A combination of closed questions and open-ended questions were thus used. Sixteen panel members participated in the first round, of which two were from Chile.

The additional criteria provided by the panel members were included in the second questionnaire. Where possible, the additional criteria were combined, but caution was exercised not to exclude any criteria that would lead to the potential exclusion of important criteria. One additional question was added to determine both the current and the future status regarding the use of contractors for harvesting. Because one of the panel members from Chile did not return his questionnaire, he was excluded from participating in the remainder of the study.

The third round questionnaire once again allowed for the consolidation of criteria based on the type of responses received from the panel members. One additional question was included to determine the future views on the size of contracts.

DELPHI STUDY RESULTS

Change drivers over the last decade

The world is undergoing constant change. Within each industry and the various sectors of a particular industry, factors can be identified, which drive the process of change. These factors are a function of the political, economical, social, technological and natural environments within which the particular industry or industry sector operates. The factors driving change, is referred to as change drivers. By identifying these drivers, one can plan to meet the expected future changes facing an industry sector. It is important to identify the core change drivers over the last 10 years and their relative importance, to have a reference of how these are expected to change in the future. The respondents were asked to weight the relative importance of the listed factors out of a score of 10. Figure 1 reflects the change drivers over the last decade.

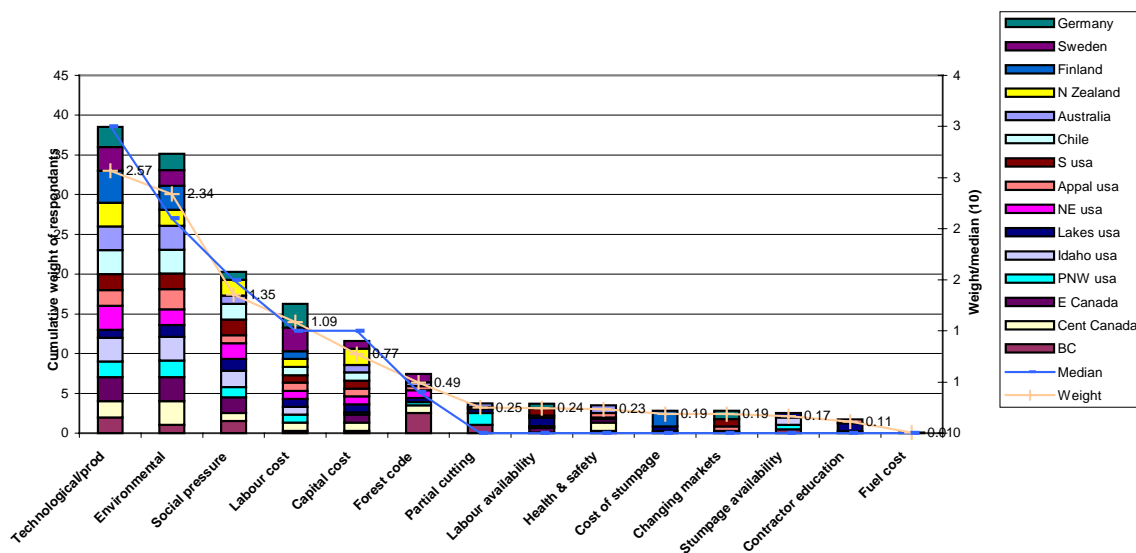


Figure 1: Global change drivers – last 10 years

Technological and productivity improvements

Technological and productivity improvements were rated as being the greatest contributor to change over the last decade (mean 2,56 and median 3,0).

Environmental impacts

There was consensus that environmental impacts was the second largest change driver in the last decade (mean 2,34 and median 2,1).

Social pressure

Social pressure was ranked the third largest contributor to change (mean 1,35 and median 1,5). Two countries, Sweden and Finland, diverged from the remainder. The reason could be due to the cut-to-length systems prevailing in these two countries, which are generally viewed as environmentally and socially acceptable harvesting systems, and the integrated role that forestry plays within Scandinavian communities.

Labour cost

Ten respondents weighted labour cost the same, while two respondents weighed labour cost higher and three weighted labour cost lower. The upper values represent Sweden and Germany, while two respondents from Canada and the one from Australia weighted the influence of labour cost lower.

Capital Cost

Capital cost was weighted 5th, while one respondent (New Zealand) weighted it higher.

The implementation of Forest Practice codes

Forest practice codes was ranked 6th. Only British Columbia weighted forest practice codes significantly higher, where they have been introducing a Forest Practice Code over the last five years (2,5 out of 10).

Other

The following change drivers were ranked as less important or unimportant over the last decade, with all having a median of zero:

	Weighting
Partial cutting	(7)
Labour availability	(8)
Health and safety	(9)
Cost of stumpage	(10)
Changing markets	(11)
Stumpage availability	(12)
Contractor education	(13)
Fuel cost	(14)

In summary, two drivers dominated change (technological/productivity improvements and environmental impacts); four drivers made an important contribution, and eight drivers were relatively unimportant.

Change drivers over the next decade

Figure 2 reflects the change drivers expected to influence harvesting systems over the next decade.

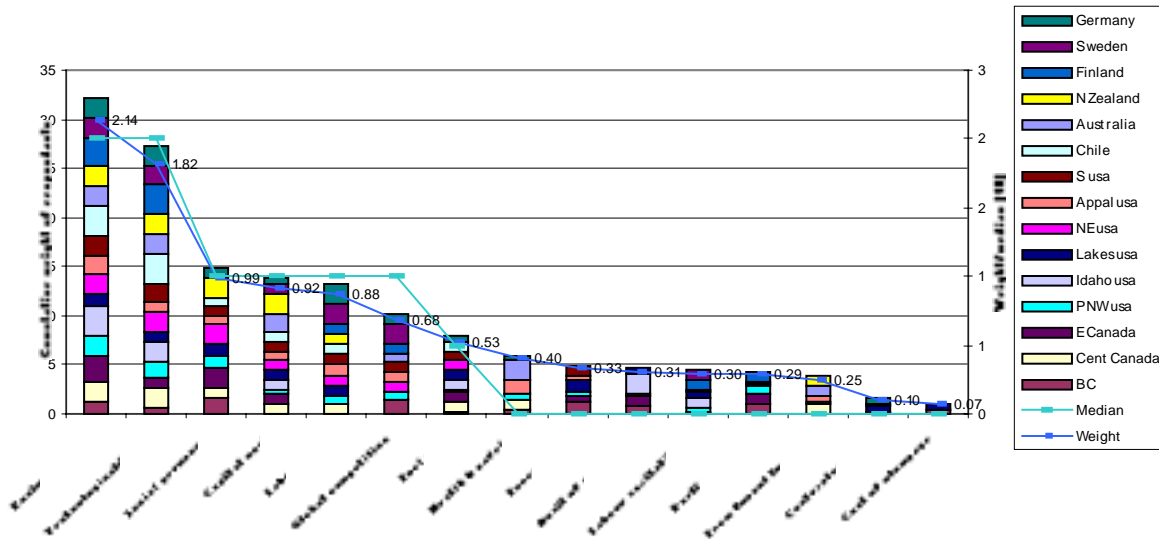


Figure 2: Global change drivers – next decade

Environmental pressures

Environmental pressures were ranked as the most important change driver in the next decade (mean: 2,1 and median: 2). Eastern Canada, the Inland Empire of the USA and Finland rated this factor higher than the remainder. The Lake States of the USA and British Columbia believe this factor will be of less significance.

Technological and productivity improvements

After environmental pressures, technological and productivity improvements are viewed as the most important change driver in the next decade, with a mean of 1,82 and a median of 2. Chile and Finland believe this to be more important than the remainder, while British Columbia rated it lower than the remainder.

Social pressure

Social pressure was ranked third, with a mean of 0,99 and a median of one. Three regions/countries, namely Eastern Canada, North East USA and New Zealand, weighted social pressure higher, while the remainder of the respondents had consensus on the weighting of this factor.

Capital cost

The cost of capital was ranked 4th, with a mean of 0,92 and a median 1. Ten of the respondents showed consensus, while Australia and New Zealand rated it significantly higher (2). There is thus no consensus regarding weighting of the cost of capital. Most significantly, Australia and

New Zealand's results deviate significantly from the remainder of the respondents. The reason could be the strong devaluation of these currencies since the economic meltdown in Asia in 1998.

Labour cost

Labour cost was ranked fifth, with a mean of 0,88 and a median of 1,0. Only two respondents believed labour cost to be more important than the remainder - Germany and the Appalachian Region of the USA.

Global competition

Global competition was weighted as the sixth most important change driver. Thirteen of the respondents showed consensus.

Fuel cost

The cost of fuel was ranked seventh (mean 0,53 and median 0,5). There was not consensus on this issue, as five countries gave it a zero weighting and seven countries weighted it as one.

Other factors

Other factors identified as change drivers were ranked as follows:

	Weighting
Health and safety	(8)
Forest practice code	(9)
Availability of stumpage	(10)
Availability of labour	(11)
Partial cutting	(12)
From forest to processing plant	(13)
Contractor education	(14)
Cost of stumpage	(15)

These factors are far less significant, with all of them having a median of 0.

From the results, one can assume that environmentally sound harvesting will become more important over the next 10 years, that technological breakthroughs will continue to increase productivity and that both the cost of labour and machines will continue to increase globally.

Changes in harvesting systems in 2010

The ranking of the changes in harvesting systems that are expected to have taken place by the year 2010 are shown in Figure 3. Where questions 1 and 2 used a weighting, the respondents were asked to rank the factors in this question. The reason for this was that opposed to only identifying the core change drivers, this question required a response to all factors listed as potential changes in harvesting systems in 2010. This could only be achieved by using a ranking system. Note that 1 is the highest ranking and 20 the lowest.

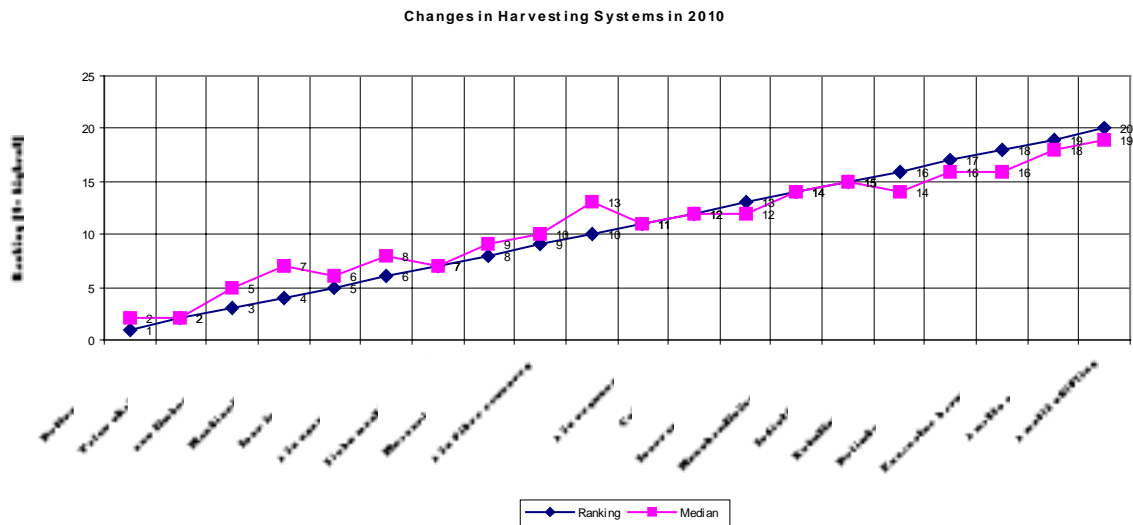


Figure 3: Changes in Harvesting Systems in 2010

Better planning of harvesting operations

Better harvest planning was ranked as the most important change in harvesting (mean 2,36 and median 2). Sweden was the only exception, being ranked 9th out of 20 criteria, possibly due to the advanced levels of planning already prevalent in this country.

A focus on the whole value chain

There was consensus on the ranking of this as the second most important change in harvesting operations in 2010. Five respondents ranked it first and seven ranked it second. The only exception was the Lake States of the USA, where it was ranked last. The reason for this is unsure. The mean ranking is 3 and the median 2.

Non-timber values

Non-timber values corresponds with the social pressure and environmental impact change drivers, both of which were rated as being very important. Similarly, the inclusion of non-timber values was ranked 3rd out of 20. Although no ranking was higher than 10, ten respondents showed consensus on this ranking. There is thus fair consensus on the ranking of non-timber values.

Machine / terrain interaction

This factor relates to more versatile mechanised systems being developed with regard to terrain conditions (i.e. slope, soil conditions, ground roughness) and was ranked 4th.

All respondents ranked it 11th or lower, reflecting fair consensus with regard to this factor.

Increase in thinnings / partial cutting

The ranking for this factor was 5th. However, it was ranked 19th for New Zealand, indicating that not all respondents believe that thinnings will replace clearcutting in the future, particularly in those countries dominated by plantation forestry. Its ranking of 5th place does, however, indicate there will be a trend towards partial cutting over the next decade.

Increase in operator skills

Due to the development of more sophisticated machinery, it can be expected that operator skills will have to increase for machines used in harvesting operations in 2010. This factor was ranked 6th. Australia, the Appalachian region of the USA and Sweden ranked it lower than the other countries, but 12 of the 15 respondents showed consensus in their ranking.

Links between machine and control room

Links between the harvesting machine and the control room refers to the use of communications technology to meet customer needs, by bucking on demand. This factor was ranked seventh, with eighth responses showing consensus. Central Canada (18), the Lake States of the USA (18) and the Southern USA (17) ranked this factor lower.

More accurate measuring on harvesters

The results indicate that new technology will improve measuring accuracy on harvesters, and was ranked eighth. There was not consensus regarding this factor, with two countries (Finland and Sweden) ranking it low and three countries (Australia, Chile and Germany) ranking it higher.

Fibre recovery

An increase in fibre recovery was ranked 9th. Ten of the 15 respondents gave a similar ranking, indicating a fair consensus. Three countries ranked it lower, namely Chile, the Appalachian region of the USA and New Zealand.

GPS

GPS was ranked 10th and had nine respondents showing consensus in their ranking. There was not consensus regarding the use of GPS, with three countries having ranked it very low and three countries ranking it very high. Irrespective of this, the use of GPS technology in harvesting machines is expected to be common practice in 2010.

Increase in ergonomics

The increase in ergonomics on harvesting machines was ranked 11th. The exception is Finland, where it was ranked last. Scandinavian machines are generally already ergonomically superior, and these countries are probably of the view that ergonomics will only show incremental improvements over the next decade. The ranking of 11th does indicate that machines built to meet the ergonomic standards set in Scandinavia, will improve significantly by 2010.

Increase in cut-to-length systems

This factor was ranked 12th out of 20. Australia, Canada and USA generally ranked it high, while countries where this system is already well established ranked it low, reflecting a divergence of opinion. This can be expected, considering the various geographic regions of the world from which the respondents came. Of importance is the fact that an increase in cut-to-length systems can be expected in regions, which are currently dominated by tree-length systems.

Increase in mechanisation

Increase in mechanisation was ranked 13th. Exceptions are New Zealand (ranked 3rd) and the Appalachian region of the USA (ranked 5th). Most of the countries represented in the study are already highly mechanised, hence the relatively low ranking of this factor.

Value recovery through processing yards

This factor was ranked 14th. Three countries considered it more important, namely, Chile (8th), the Appalachian region of the USA (7th) and the Pacific Northwest of the USA (4th).

Infield chipping

Infield chipping refers to the use of DDCL systems (as developed in North America) and the application of mobile chippers (as developed in Scandinavia). Infield chipping was ranked 15th, with 13 of the respondents showing consensus. The only country receiving a high ranking was Australia, where it was ranked fourth.

The use of robotics technology

There was consensus that robotics technology in harvesting equipment has a relatively low ranking. Although many researchers believe that robotics will substitute most of the respective operator functions, the results of this study indicate that only marginal progress will be made by 2010.

Sophistication levels of delimiters

The importance of stroke boom delimiters also extracting grade material in future was ranked low (17th). No country gave this factor a high ranking.

Use of excavator base carriers for harvesters

An increase in the use of excavator base-carriers for harvester heads was ranked 18th. It was ranked fifth for Australia, and ranked last and second to last by Finland and Germany respectively.

An increase in cable yarding

It is important to note that cable yarding, although ranked 19th, was ranked first by New Zealand and second by the Appalachian region of the USA. There is thus not consensus on this factor, indicating that some panel members believe that cable yarding will replace ground-based systems in future. This is primarily influenced by the prevailing terrain conditions in various regions of the world, and how these will change over the next decade, as the sites being harvested change, or as there is a need to change harvesting methods for environmental or social reasons

Multi-shifting of harvesting machines

Multi-shifting was ranked last by the panel. The exception was the Lake States of the USA, where it was ranked 3rd. Considering the high importance of the cost of capital as a change driver, it would have been expected that multi-shifting would in future be used to negate the high cost of capital. However, there is consensus amongst most panel members that multi-shifting will not increase significantly by 2010, compared to current levels of machine utilization.

Outsourcing of harvesting operations

Questions 8 and 9 of the study focused on future patterns regarding the outsourcing (or contracting) of harvesting operations. Question 8 focused on the percentage of volume outsourced by forestry companies, while question 9 focused on the size of the future contracts.

Figure 4 shows that 84% of current harvesting operations included in the study are outsourced. This figure is expected to increase to 90% by the year 2010. This question only passed through two rounds of the Delphi study because all respondents agreed that outsourcing will increase in the future.

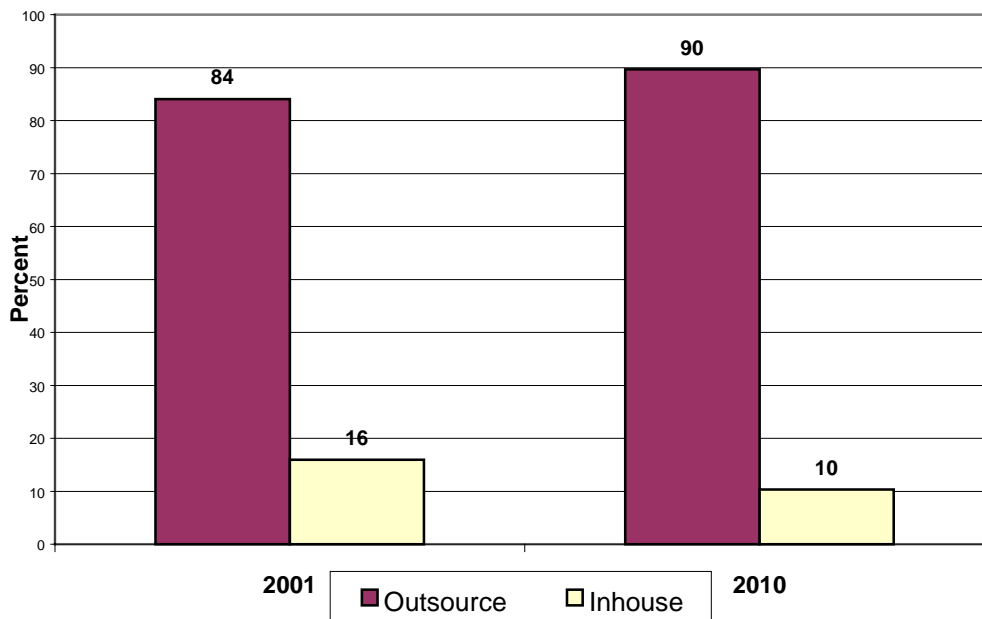


Figure 4: Outsourcing versus in-house harvesting operations 2001 vs. 2010

The question on annual contracts was only included in the last round of the study and these results are therefore only indicative of possible trends. Figure 5 reflects the size of the annual contracts put out to contractors for ground-based harvesting. The answers reflect how companies view the size of the contracts that they are working with at present and how this is expected to change in 2010. Five of the 15 respondents were not willing to answer this question, due to the lack of information for their region/country. The results indicate that contract sizes will increase by 2010. Only 33% of annual contracts are expected to be less than 50 000m³ per year, as opposed to the current 44%. This trend is also reflected in the 100-200 000m³ and 200-500 000m³ contract sizes. The figures are 16% in 2001, as opposed to 21% in 2010 and 10% in 2001, as opposed to 13% in 2010 respectively.

From the results it can be concluded that not only will the outsourcing of harvesting operators increase, but also the size of annual contracts.

Future requirements of harvesting foresters and contractors

The Delphi study included two questions regarding the future requirements (or knowledge and skills base) of harvesting foresters and contractors. Panel members were asked to rank (separately) the most important requirements of a harvesting forester and harvesting contractor in 2010. Figures 6 and 7 show the results of the respondents. A ranking system was once again used for these two questions. The ranking required the respondents to give a value to each factor, thereby avoiding the probability of some factors being totally ignored/discredited, which could be important in the education and training of harvesting persons. A harvesting forester refers to a company-employed forester who either manages contractors or runs in-house harvesting operations for the company he is employed by. A harvesting contractor was defined as an individual running a harvesting operation and who is contracted by a forestry company or processing company to do the harvesting.

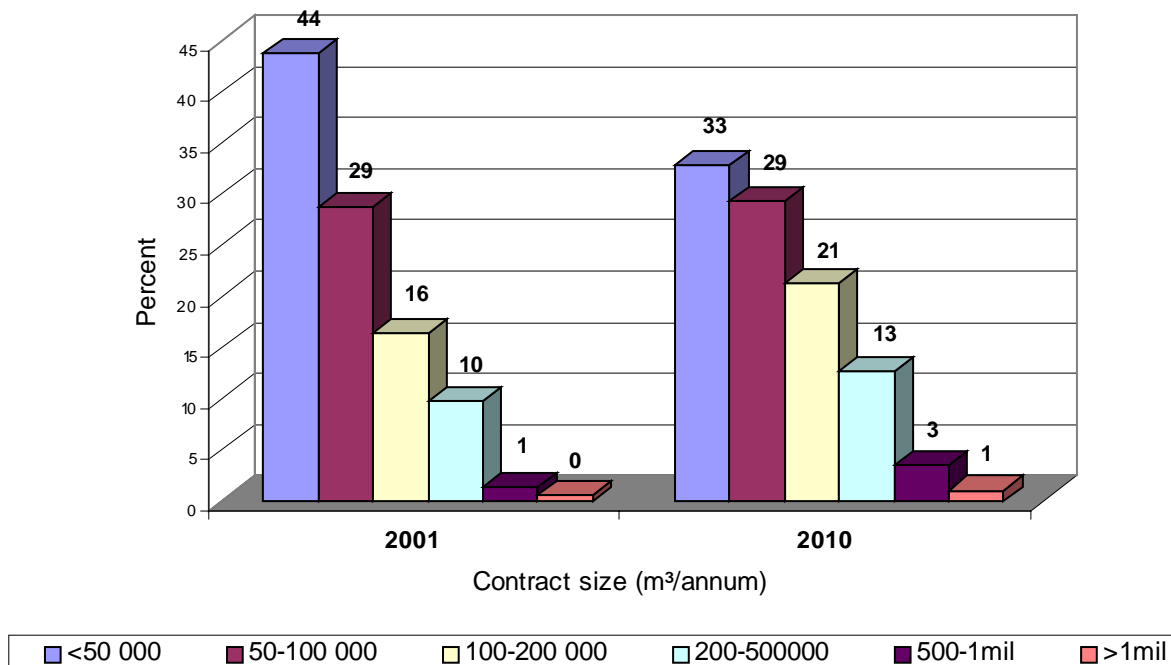


Figure 5: Timber harvesting contract sizes: 2001 versus 2010

Inter-personal skills

Inter-personal skills were rated as the most important requirement for a harvesting forester and ranked 4th with regard to a harvesting contractor. Twelve of the 15 respondents showed consensus in their ranking, with the highest ranking by any respondent being 3rd for a harvesting forester. This supports the high level of consensus amongst respondents as being the number one requirement. Interestingly, as with management skills, this is typically not a forestry-related subject, and may not be taught at forestry faculties.

However, it could be quite simple to modify existing curricula to enhance the inter-personal skills of students. This can be done through the following ways:

- Allow for as much group work as possible.
- Regularly mix groups around so that students learn to work with different people.

- Allow free debating of subject matter in class.
- Have students regularly present their work to the remainder of the class, thereby teaching them presentation skills in the process.

Business skills

This refers to an understanding of strategic management, financial management, marketing, risk assessment, the use of electronic-business and personal stress management.

Business skills are the only requirement where there is a significant deviation from the ranking of the panel members for a harvesting forester (5th) and a harvesting contractor (1st). Business skills are relatively important for a harvesting forester, but are seen as the most important attribute for a harvesting contractor to possess.

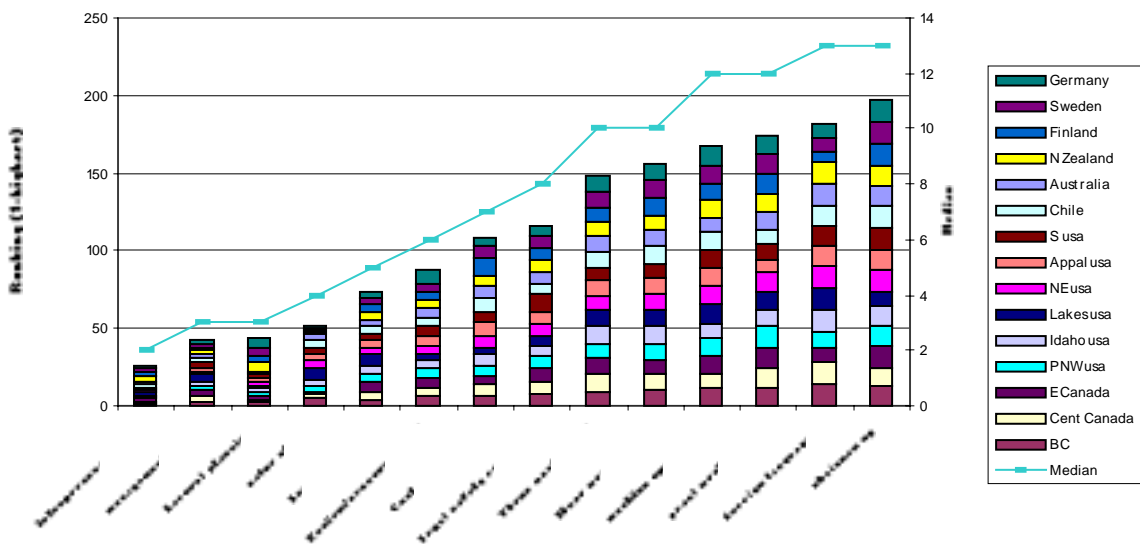


Figure 6: Skill requirements of a harvesting forester in 2010

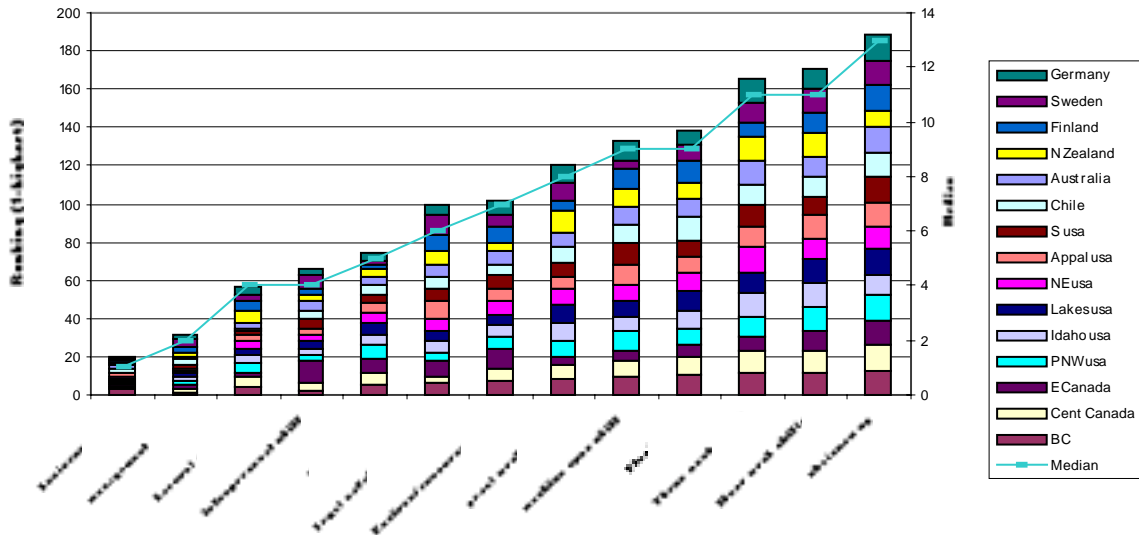


Figure 7: Skill requirements of a harvesting contractor in 2010

The debate on the relevance of business courses in a curriculum is not unique to forestry, e.g. the engineering, accounting, agricultural and legal professionals face the same questions. However, there is a danger that if a greater emphasis is placed on these courses in the future, they may substitute for the technical forestry courses. This situation should be avoided, as core forestry courses remain the essence of a forestry curriculum.

As with management and interpersonal skills, instructors should search for ways of conveying the teaching of sound business principles through their traditional forestry subjects. An example would be to include business principles into the core subjects of harvest planning, such as:

- The process of resource allocation is already part of harvest planning.
- Strategic, tactical (3-5 year) and operational planning.
- The annual budgeting of a harvesting operation.
- The day-to-day planning and control required in a harvesting operation.

Management Skills

This refers to the traditional management roles of planning, leading, organising and controlling. It also includes labour relations. This factor was ranked as the 2nd most important requirement for both harvesting foresters and contractors.

Although management skills have been so highly rated, it is strictly speaking not a forestry related subject. The high rating suggests that management skills should somehow be worked into forestry curricula through the courses being offered. Students can be taught management skills through the approach used by instructors to convey technical subject matter.

Harvest planning

The ability of both harvesting foresters and contractors to plan harvesting operations was ranked 3rd. Eleven and thirteen of the respondents showed consensus in their responses for a harvesting forester and a harvesting contractor respectively.

Supply chain knowledge

Harvesting systems and value chain knowledge refers to the ability to assess machines for a particular application, the combining of machines to optimise the value chain and the ability to cost out a system. Harvesting foresters should also have knowledge to identify techniques for increasing profit through cost reduction or value adding in the supply chain. This requirement was ranked fourth for harvesting foresters and fifth for harvesting contractors. Fourteen and ten respondents showed consensus in their ranking for harvesting foresters and contractors respectively, indicating consensus regarding the importance thereof. This should thus form the core subject in tertiary harvesting education courses.

Environmental and resource management skills

The need to understand environmental and natural resource issues was ranked 6th for a harvesting forester and 7th for a harvesting contractor. There is strong consensus on the ranking from panel members (11 panel members ranked this factor at 6 for a harvesting forester and 7 for a harvesting contractor).

Contractor management

This factor is only obviously relevant to the requirements of a harvesting forester and was ranked 7th. There wasn't consensus regarding this ranking.

Legal safety requirements

This requirement was ranked 8th for a harvesting forester and 6th for a harvesting contractor. Safety issues have been a very prominent factor in harvesting operations over the last decade, and the consensus of respondents is that it will remain relatively important over the next decade. Twelve respondents showed consensus in their ranking for a harvesting forester and also for a harvesting contractor.

Theoretical mechanical knowledge

Theoretical mechanical knowledge refers to the theory of the internal combustion engine, the drive train and the electrical systems applicable to harvesting machines.

There is consensus amongst the panel members on the ranking of this requirement (9th out of 14) for a harvesting forester and 11th out of 13 for a harvesting contractor. It is thus clear that this should not be a major portion of the tertiary education curriculum, but it should be included to the extent that students are given a sound understanding of the functioning of a machine.

Theoretical mechanical skills

This factor refers to an understanding of the requirements for repairing and servicing of a machine. It was ranked 10th for a harvesting forester and 12th for a harvesting contractor. As with theoretical mechanical knowledge, the theory of repairs and maintenance needs to be taught to students, but at a relatively superficial level.

Machine operator skills

This refers to the ability to physically operate a machine. This factor was ranked 11th for a harvesting forester and 9th for a harvesting contractor, indicating a relatively low level of importance. Ten of the 15 respondents showed consensus in their ranking for a harvesting forester and 12 for a harvesting contractor. As with mechanical skills, it is important for harvesting foresters to have some application of machine operators and other practical harvesting skills.

Practical mechanical skills

This factor refers to the ability to repair and service a machine. It was ranked 12th for a harvesting forester and 9th for a harvesting contractor. This factor is thus relatively unimportant.

Foreign languages

A foreign language was only seen as a requirement for a harvesting forester and not a contractor. It was ranked 13th out of 14 factors and is thus not deemed important with regard to tertiary forestry education. Rankings ranged between 7 (Finland) and 14. This factor, however, is a broader societal issue related of the demographics of each particular region or country.

Chainsaw operator skills

This requirement was ranked last for both harvesting foresters and contractors, indicating the progressive redundancy of chainsaws, as the technology of alternative systems continues to improve.

Flexibility

Equipment flexibility refers to the ability of a contractor to use equipment over a range of site and stand conditions and for the contractor to be skilled in using a range harvesting machines. The issue of flexibility of equipment was only applicable to harvesting contractors and was ranked 13th.

Tertiary institutions, both nationally and abroad will need to include the factors discussed from this study as part of their core Forest Engineering and/or harvesting programmes. It is important to note that business skills, management skills, inter-personal skills and contractor management skills can be taught through traditional Forest Engineering subjects. The same material can be used, but must be conveyed to students in another format, to meet the above requirements. Adult learning and continuing education programmes have become an increasingly important mechanism to fulfil the demands for new skills. Employers of new graduates may need to provide pre-service training programmes on specific subjects not covered by their formal training. There is also a growing reliance on continuing education or in-service training to give mid-career personnel new knowledge and skills.

CONCLUSION

From the results of this study, it can be seen that the two most prominent change drivers over the last decade and those forecast for the next decade will remain the same. These two are technological/productivity improvements and environmental impacts. However, it is expected that the relative importance of environmental impacts will become even greater than that of technological/productivity improvements in the future. These two change drivers will dominate in their influence on the future harvesting systems used globally.

When considering the impacts of these change drivers, then one will expect that there will be a greater focus on the sounder planning of harvesting operations and that foresters will need a greater understanding of the complete supply chain, from stump to mill. Non-timber values will become of greater importance and foresters will need to understand and manage these values on a day-to-day basis. This should lead to an increase in cut-to-length systems.

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