IUFRO EKE Working Party Achieves Success with Kenora Conference

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Serving as a Deputy with the Extension and Knowledge Exchange (EKE) Working Party of IUFRO (International Union of Forest Research Organizations) has been and continues to be a rewarding experience for me personally. And taking on the role of local host for our international conference in Kenora this past September was also very positive. It was just last year at the conclusion of our Working Party's event in Galway Ireland (2015) that I volunteered to host the next session, thinking immediately that Kenora would be an excellent location, with the CIF/IFC's successful 2015 AGM and conference in Lake of the Woods Section being a fresh memory.

This year's EKE conference theme and that of the six papers collectively presented in this issue: *Increasing capacity for program delivery through knowledge exchange networks and peer-to-peer learning,* speaks to all of us who work in forest extension, knowledge exchange, technology transfer and broader forest education. It asserts that there is a need for innovative and creative approaches to program delivery, especially with ever-decreasing resources and funding. The Kenora conference presentations focused on effective EKE approaches that engage forest stakeholders and communities by encouraging their direct participation in program development and delivery—to truly address their needs. Finding a local "champion" and utilizing peer-to-peer learning can also be quite effective in increasing the capacity for all who work in extension and knowledge exchange. The presentations and the papers cover a wide range of approaches to this engagement and dissemination, and participants represented a variety of disciplines including agroforestry, community development, forest products, biofuels, prescribed fire, and social science. The conference

IUFRO Working Group participants at the Experimental Lakes Area long-term ecological research theme was chosen precisely to encourage interdisciplinary interaction and networking. The international diversity of participants is noteworthy, with delegates from across Canada and the U.S., and from Ireland, Sweden, New Zealand, and Bangladesh. This diversity and the modest size of the conference itself were conducive to close interaction and intimate dialogue that is often not possible at larger events.

My personal vision and that of our FPInnovations Team in Ontario is to make several locales and venues in our province preferred destinations for forest extension and knowledge exchange. We certainly achieved this with the Kenora EKE event, and it was not all work either—our delegates enjoyed some unique northern Ontario hospitality including an outdoor fish fry, some great local music, and a few surprises including wild rice popcorn courtesy of some Indigenous Elders we met up with one evening. And I would be remiss if I did not mention that conference participants spent an enlightening day at the Experimental Lakes Area (ELA), not all that far a drive from Kenora. ELA is an area of 58 lakes reserved for conducting long-term ecological research. It would not be exaggerating to say that it was one of the best field tours I have ever experienced during my 35 career—and I have participated in many! Our guide was animated, engaging and knowledgeable, and the facilities and science of the tour were world-class.

In closing, I want to thank all of the participating delegates, my counterparts on the IUFRO EKE Working Party—especially our Chair Janean Creighton of Oregon State University, our dedicated staff with both the CIF/IFC and FPInnovations, and our generous sponsors. Together we made a highly beneficial and enjoyable event happen in northwestern Ontario; the papers in this issue will certainly provide favorable understanding into the depth and insight that was achieved.

La session du Groupe de travail sur le transfert et le partage des connaissances de l'IUFRO couronnée de succès lors de la conférence de Kenora

Je considère que le poste de directeur adjoint du Groupe de travail sur le transfert et le partage des connaissances (TDC[1]) de l'IUFRO (l'Union internationale des instituts de recherche forestière) continue d'être pour moi une source d'expérience enrichissante. De plus, il m'a donné la chance de pouvoir accueillir notre conférence internationale à Kenora en septembre dernier. En effet, l'an dernier, à la toute fin de l'activité du Groupe de travail à Galway en Ireland (2015), j'ai proposé d'organiser la prochaine session, convaincu d'avance que Kenora serait un endroit idéal, compte tenu du succès qu'avait connu le congrès 2015 de l'IFC/CIF organisé par la section Lake of the Woods.

Cette année, le congrès du Groupe TDC avait pour thème *Accroître la capacité à livrer des programmes au moyen des réseaux d'échanges de connaissances et l'apprentissage entre pairs.* C'est aussi le thème des six articles de ce numéro qui interpellent sans doute tous ceux et celle qui travaillent dans le domaine des services d'information, des échanges de connaissances, du transfert technologique et de la formation générale en foresterie. Ce thème fait ressortir la nécessité d'adopter des approches novatrices et créatives pour livrer les programmes, surtout lorsque les ressources et le financement ne cessent de diminuer. Les présentations livrées lors de la conférence de Kenora ont porté sur les approches de TDC efficaces qui impliquent directement les intervenants forestiers et les communautés dans l'élaboration et la livraison des programmes —afin qu'ils répondent le mieux possible à leurs besoins. On peut aussi miser sur un porte-parole du milieu et l'utilisation de l'apprentissage entre pairs pour renforcer les capacités de ceux et celles qui œuvrent dans le domaine du transfert et des échanges de connaissances. Les conférences et les articles portaient sur une vaste gamme d'approches pour favoriser l'implication et le partage des connaissances; ils s'adressaient à un auditoire varié représentant les domaines de l'agroforesterie, du développement communautaire, des produits forestiers, des biocarburants, du brûlage dirigé et des sciences sociales. Le thème de la conférence avait été soigneusement choisi afin de favoriser les interactions et le réseautage entre les différents secteurs. Il est intéressant de noter au surcroît à la diversité des participants à l'échelle internationale, venant qui du Canada et des É.-U. qui de l'Irlande, de la Suède, de la Nouvelle-Zélande ou du Bangladesh. Cette diversité et le faible nombre de participants ont favorisé une interaction plus étroite et un dialogue plus rapproché, choses qu'il n'est pas possible de faire lors d'événements de grande ampleur.

Mon opinion, que partage également l'équipe de FPInnovations en Ontario, est de privilégier une multiplicité de lieux d'installations en province comme destinations privilégiées pour le transfert et le partage des connaissances. Nous avons certainement atteint cet objectif lors du congrès de TDC qui s'est tenu à Kenora, puisqu'en plus de travailler les participants ont eu droit à des activités à saveur touristique. Ils ont ainsi pu apprécier l'hospitalité légendaire des Nord-Ontariens, notamment lors d'un repas de poisson en plein air accompagné de musique locale, en plus de quelques surprises comme une dégustation de riz sauvage soufflé offert par les Anciens d'une nation autochtone lors d'une rencontre en soirée. Et ce serait de la négligence de ma part si je ne mentionnais pas que les participants au congrès ont passé une journée mémorable dans la région des lacs expérimentaux (RLE) non loin de Kenora.

[1]Extension and Knowledge Exchange (EKE) Working Party of IUFRO

La RLE est un territoire comportant 58 lacs protégés à des fins de recherche écologique à long terme. Je n'exagérerais pas en affirmant que cela aura été l'une des meilleures excursions techniques à laquelle j'ai participé en 35 ans de carrière—et, laissez-moi vous dire que j'en ai fait plusieurs! Notre guide était dynamique, intéressant et bien informé, et les installations et les aspects scientifiques de l'excursion étaient de niveau international.

En terminant, j'aimerais remercier tous les participants, mes collègues du Groupe de travail TDC de l'IUFRO—notamment saprésidente, Janean Creighton, de l'Université de l'Oregon, le personnel dévoué du l'IFC/CIF et de FPInnovations et nos généreux commanditaires. Ensemble, nous avons pu créer un événement très instructif et plaisant dans le nord-ouest de l'Ontario; les articles de ce numéro apporteront certainement un meilleur éclairage sur les enjeux et les préoccupations des participants à cet événement.

Re: Canadian Forestry Education – Thoughts of a Recently Retired Professor *(The Forestry Chronicle*, 2016, Vol. 92, No. 3)

I agree with Dr. Rodney Savidge's contention that forest management should have a strong basis in science. If we can study something called "political science", we should certainly be able to study "forest science". Where we diverge is with regard to what you need to know in order to manage a forest in the 2First century.

I am responsible for the management of all aspects of 2600 acres of County Forest in south-central Ontario. On any given day, this can include: trying to get horseback riders, mountain bikers, and loggers to work together; answering inquiries about dying porcupines; giving landowners advice about emerald ash borer management; trying to explain (for the 1000th time)—politely—why a "messy forest" is not a problem; and giving politicians *Forestry 101* lessons. Once in a while, I get to do what I went to school for—forest inventory, silvicultural prescriptions, and the like. Is it really necessary for me to remember all of the detailed physiology and autecology information that underlies the management strategies I employ? Forestry education, as I remember it, was progressive—starting with chemistry, photosynthesis, etc. and using these elements to build on in later years when learning what impact management decisions might have.

Forests are very complex ecosystems and there are many things about them we do not know—and may never know—but in the meantime we are doing our best and adapting our management to new information. This is why I read publications such as *The Forestry Chronicle*—so that I can improve my management strategies and learn the scientific basis for my everyday observations. Just one recent example: my summer student (who is currently studying forestry at the University of New Brunswick) and I had numerous discussions over the course of the field season about why certain stands were regenerating better than others. Lo and behold, an article in the August, 2016 issue of *Forest Science* lent some research data to what we were observing: *Local Seed Source Availability Limits Young Seedling Populations for Some Species More Than Other Factors in Northern Hardwood Forests*.

We should aim to create a symbiotic relationship in forestry—a national Centre of Tree Science, where those inclined to do so can research the 16 successive steps of bordered-pit formation and the rest of us can continuously learn from that research to improve our management of Canada's forests.

Caroline Mach, R.P.F.

Relating extension education to the adoption of sustainable forest management practices

by Maminiaina S. Rasamoelina[1], James E. Johnson[2,*] and R. Bruce Hull[3]

ABSTRACT

Family forest lands represent a vitally important economic, environmental, and social resource in the U.S. A study of family forest owners was conducted in Virginia in 2007 to determine the relationship between attendance at Extension Service educational programs and the adoption of sustainable forest management practices. A mail survey was conducted to 3435 randomly selected forest owners, with a usable response rate of 32%. Participation in educational programs was shown to be significantly related to higher levels of adoption for all seven categories of sustainable forest management practices studied. For example, in the woodland management category, participants in workshops offered through the Virginia Forest Landowner Education Program (VFLEP) adopted one or more specific practices at a rate of 94%, significantly greater than 83% for forest owners who attended other general educational programs, which in turn was significantly higher than the 75% adoption rate for forest owners who did not attend any educational programs. Two key indicators of sustainable forest management are the preparation and use of a forest management plan, and the use of professional technical assistance providers. For both of these categories participants in the VFLEP adopted at significantly higher rates, 41% and 73%, respectively.

Keywords: sustainable forest management, extension, adoption, educational evaluation, private forest landowners

RÉSUMÉ

Les boisés familiaux constituent une ressource économique, environnementale et sociale d'une importance capitale aux É.-U. On a mené en 2007 une étude sur les propriétaires de boisés familiaux de Virginie afin de voir s'il y avait une relation entre les inscriptions aux programmes de formation des services forestiers et l'adhésion à la foresterie durable. Ce sondage s'est fait au moyen d'un sondage postal auprès de 3 435 propriétaires de boisés privés choisis au hasard qui a donné 32 % de réponses utilisables. Le sondage révèle une relation significative entre la participation aux programmes de formation et une forte adhésion aux sept catégories de techniques d'aménagement forestier durable étudiées. À titre d'exemple, dans la catégorie de l'aménagement des boisés, les participants aux ateliers offerts par le Virginia Forest Landowner Education Program (VFLEP) ont adopté une ou plusieurs des techniques spécifiques dans une proportion de 94 %; c'est un pourcentage significativement plus élevé que les 83 % pour les propriétaires de boisés privés qui ont participé aux autres programmes généraux de formation; ce pourcentage était lui-même significativement plus élevé que celui de 75 % pour les propriétaires de boisés privés qui n'avaient participé à aucun programme de formation. Cette étude a retenu deux principaux indices de l'aménagement forestier durable soit l'élaboration et l'utilisation d'un plan d'aménagement forestier et le recours à des services techniques professionnels. Les participants aux ateliers du VFLEP les ont adoptées dans des proportions significativement plus élevées de 41 % et de 73 % respectivement.

Mots clés : aménagement forestier durable, service de formation, adoption, évaluation de la formation, propriétaires de boisés privés

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Introduction

The United States is rich in forest land, with a total of nearly 300 million ha scattered across all 50 states. Interestingly, 56% of this forest land is privately owned, with 35% in the category of family forest land (Butler 2008). Nationally there are about 10.4 million family forest owners, who collectively own nearly 104 million ha. The average size of a family forest is about 10 ha (Butler 2008), though the majority of landowners own much less. These private forest lands are vitally important to society, as well as to the owners themselves. They provide a wide array of social, economic, and environmental benefits to society, including wood for a variety of products, habitat for fish and wildlife, clean water, recreation and scenic beauty, and open space. Therefore, society has a particular interest in the stewardship of these private lands, and in the U.S. both state and federal governments have long provided assistance for family forest owners in the form of educational programs, technical assistance, and financial incentive programs (USDA Forest Service 1998).

In Virginia, about 402 000 family forest owners own collectively over 3.9 million ha (Butler 2008). A fairly high proportion (45%) is owned by retirees, with 33% owned by working professionals, 11% by blue collar workers, and 11% by farmers (Birch *et al.* 1998). In Virginia, about 17% have a written management plan (Birch *et al.* 1998), which is well above the national average of 3.6% (Butler 2008). Virginia has had a long history of providing services to family forest owners. The Virginia Cooperative Extension Service has had a Forestry Extension Program in the state since 1925. The Virginia Department of Forestry has provided technical assistance for management, reforestation, and harvesting for many years, and more recently has assisted with recommending and monitoring the use of best management practices for water quality and enhancing site productivity.

In order to improve educational services to Virginia's family forest owners, in 1996 the Virginia Forest Landowner Education Program (VFLEP) was created through a partnership with the Sustainable Forestry Initiative, the Virginia Forestry Association, the Virginia Department of Forestry, and Virginia Tech's College of Natural Resources and Cooperative Extension Service (Johnson *et al.* 2004). The objective of the VFLEP is to educate Virginia's family forest owners and encourage them to:

- Obtain professional technical assistance;
- Develop and implement a written management plan;
- Utilize financial assistance through multiple cost-share programs, if applicable; and,
- Adopt sustainable forest management practices.

VFLEP is a highly interactive program, with input and feedback provided by family forest owners through multiple, geographically-based Forest Landowner Councils scattered across the state (Johnson 2000). These Councils are empowered to deliver, using local professional foresters as instructors, a series of 12-hour workshops designed to achieve the objectives listed above. From October 1997 through February 2004, nearly 2000 family forest owners had attended one or more of the following three workshops: Woodland Options; Wildlife Options; and, Timber Harvesting and Marketing. In recent years, additional workshops such as Financial Assistance Options and Forest and Farmland Conservation Strategies have been added to the mix.

This study was established to evaluate the effectiveness of the three original VFLEP workshops in moving the forest owner participants toward adoption of sustainable forest management practices.

Methods

We had three main groups within the forest owner target population: owners who had attended at least one of the VFLEP shortcourses; owners who had not attended any of the three courses offered under the VFLEP program but attended at least one other educational program related to forest management; and, owners who attended neither the VFLEP courses nor any other educational program. The three groups had a common denominator in that all forest owners had been exposed to a common level of awareness concerning the possibility of attending educational programs through the Virginia Forest Landowner Update newsletter. This paper focuses on the hypothesis that there are no differences in adoption of sustainable forest management practices between the three groups of family forest owners.

The study population for this research included family forest owners who were listed in the VFLEP database. This large database had been compiled over many years, and consisted of forest owners who attended some type of educational programs offered through the Virginia Cooperative Extension Service, as well as forest owners selected at random from county tax rolls. All forest owners in the database who owned at least 0.8 ha of forest land in Virginia were included, resulting in a survey population of 5793 forest owners. A proportionate stratified random sampling design was used to select 3435 forest owners (60% of the survey population), which kept the same proportions of individuals in the three groups in the final sample as in the original population. Thus, the final sample included 1038 owners in the VFLEP group and 2397 in the non-VFLEP group. The third group was developed following the survey.

For validity purposes, the survey questionnaire was pilot tested; it was mailed to 120 family forest owners using an advance letter that alerted them to the survey, followed by the survey package (cover letter, questionnaire, self-addressed stamped return envelope) a week later. For practical reasons, the pilot test was conducted with forest owners living in Montgomery County, Virginia. After all responses from the pilot test were gathered, a focus group consisting of local family forest owners was held to ensure the validity of the questions. Focus group participants made comments, and provided suggestions about unclear questions which had been identified in the pilot test. The focus group was also used to obtain input from respondents about the presentation of the survey (length, format, wording of questions, font size).

The questionnaire was mailed after analysis of the pilot test, and correction and revision following the focus group. It was administered using a slightly modified version of the tailored-design method (Dillman 2000) by using two waves of mailings of the survey packet (advance letter, cover letter, questionnaire, self-addressed stamped return envelope), and a wave of reminder cards to initial non-responders after a month. The first mailing was in late April 2007. A month after the first reminder card was sent, a second mailing was made of the survey packet together with a further reminder, for non-respondents. Recipients were requested to return the questionnaire even if they did not fill it out, and to provide a reason why it was not filled out.

The potential bias of non-response was evaluated by comparing late and early returners of the questionnaire. We assumed that non-respondents would be similar to late returners so we compared demographic characteristics (age, level of education, household income, land size, length of ownership) using an independent t-test to compare means (Groves *et al.* 2002). Six of the seven characteristics were not significant ($p > 0.94$): land size, length of ownership, age, level of education, total household income, and percentage of income gained from forest-related activities. Only the distance between the specific residency and the nearest forest tract owned was significant ($t = 2.127$; p-value 0.034), with early returners of the questionnaire living farther from their forest land than late returners. In light of these results, we considered non-response bias to be minimal and did not conduct further tests.

Through the survey, the respondents were queried as to their adoption of one or more practices following their attendance at educational programs or, in the case of those forest owners who did not attend any educational programs, adoption was independent of program attendance. Adoption was defined as use of one or more of the practices in a category.

The testing hypothesis was that there was no significant difference in adoption of various sustainable forest management practices among the three categories of forest owners. The hypothesis was tested using a one way Analysis of Variance (ANOVA). When the ANOVA results showed significant differences at the 0.10 level, we used a *post-hoc* test to identify which groups differed. The method used for the *post-hoc* test depended on whether there was equality of variance across the three groups. The Levene test was used to test the equality of variance (if its result shows a significant difference, then unequal variance is assumed, but if not, equal variance is assumed). Depending on the outcome of the test of equality of variance, either the Tamhane's test (which is based on the t-test), or the Fisher's Least Significant Difference (LSD) method was used to determine which means differed. The first was used if variances were unequal and the second for equal variances. All tests used a level of significance of 0.10. The requirements proposed by Lunney (1970) for the use of ANOVA with dichotomous variables were followed for each of the tests.

Results and Discussion

Demographics

The survey respondents were placed into one of three categories: (a) those who had attended one or more of the VFLEP workshops; (b) those who did not attend a VFLEP workshop, but had some other experience with extension education, such as field tours; and, (c) those who had no experience with forestry-related educational programs of any type. We labeled these as (a) VFLEP, (b) Other, and (c) None. The distribution of respondents by category is shown in Table 1. Of the 1097 respondents (32% response rate), nearly half (45%) attended one or more of the VFLEP workshops. Additional demographic variables are shown in Table 2. Differences in demographics between the categories were relatively minor. Forest owners who attended educational programs tended to be a little younger and more affluent than those who did not attend any educational programs. Also, VFLEP attendees owned larger forests, 86 ha compared to 53 ha for the other two categories. Respondents were asked to self-rate on an adoption scale of 1 to 5, where 1 is equivalent to an innovator and 5 a laggard, using the scale of Rogers (2003). Forest owners who did not attend any educational programs averaged 2.6 (between early adopter and mid-range adopter), while forest owners in the other two categories averaged 3.2 (VFLEP) and 3.3 (Other), equivalent to a mid-range to late adopter.

Additional details related to a demographic analysis of the three categories can be found in Rasamoelina *et al.* (2009).

Table 1. Distribution of respondents by educational category (n=1 097)

Category	No. of Respondents	%
VFLEP	489	45
Other	287	26
None	321	29

Table 2. Demographic variables by education category

	Education Category		
Demographic Variable	VFLEP	Other	None
Age (yrs.)	62	60	65
Level of Education[a]	4.4	4.7	3.6
% income from forest	2.6	4.3	2.4
Household income[b]	3.1	3.2	2.8
Size of forest (ha)	86	53	53
Distance from home to forest (km)	43	19	49
Self-rated adoption[c]	3.2	3.3	2.6

[a]Level of education: Scaled from 1 to 6, where 1 is < 12th grade and 6 is graduate degree; 4 = associate or technical degree.
[b]Household income: Scaled from 1 to 5, where 1 is < $25 000 and 6 is $200 000 or more; 3 is $50 000 to $100 000.
[c]Self-rated adoption: Scaled from 1 to 5, where 1 is an innovator and 5 is a laggard using the scale of Rogers (2003). 2 equates to an early adopter and 3 to a mid-range adopter.

Adoption of Sustainable Forest Management Practices

Sustainable forest management practices are those that lead to a resilient and healthy forest that is capable of providing social, environmental, and economic benefits into the future, and are implemented such that forest owners provide their "fair share" of values to society without unfairly exploiting or depriving themselves of values to the detriment or benefit of people in another place or time (Oliver 2003). In our study we categorized sustainable forest management practices as follows: (a) woodland management practices; (b) wildlife management practices; (c) harvesting management practices; (d) development and use of a written forest management plan; (e) use of professional technical assistance; (f) use of financial assistance programs; and, (g) use of conservation easement programs. Woodland management practices included silvicultural techniques such as thinning, pruning, prescribed

Table 3. Adoption rates (percent) for sustainable forest management (SFM) practices by forest owners in three educational categories

SFM Practices	Adoption Rate (%)		
	VFLEP	Other	None
Woodland management	94 a[a]	83 b	75 b
Wildlife management	82 a	74 a	74 a
Harvesting best management	65 a	89 b	66 a
Management plan	41 a	22 b	12 c
Technical assistance	73 a	44 b	35 b
Financial assistance	22 a	36 b	9 c
Conservation easements	6 a	11 a	6 a

[a]Adoption rates within a row followed by the same letter are not significantly different at the 0.10 level.

burning, controlling invasive weeds, tree planting, and fertilizing, as well as some more standard practices such as maintaining painted boundary lines, roads, gates, and culverts (Table 3). Wildlife management practices included enhancing and protecting habitat, controlling invasive weeds, establishing food plots and nesting boxes, installing water holes or ponds, and protecting special places like springs and vernal pools. Harvesting management practices, for those landowners who had harvested trees, included the use of a written contract with a logging contractor, use of marking for designating the trees to harvest, use of a timber cruise to determine the volume of timber to harvest, and use of a regeneration plan (Table 3). Harvesting best management practices (BMPs) are voluntary in Virginia and are prescribed by the Virginia Department of Forestry. They include the use of water bars or other water control structures on roads and skid trails, maintenance of a minimum streamside management zone, and other practices for operations on wet soils to avoid soil damage and unacceptable levels of runoff and sedimentation.

The adoption rates for the various categories of sustainable forest management practices are presented in Table 3. In four out of the seven categories (woodland management, wildlife management, management plan, technical assistance), the VFLEP attendees adopted at a significantly higher rate than either the Other or None categories. Since these were three key objectives of the educational programs, that is certainly confirmation that the educational programs were on target. Foresters and forest owners alike often cite increased educational opportunities as important to increasing management of their woodlands (Jones *et al.* 1995, Londo and Monaghan 2002, Downing and Finley 2005). Interestingly, the forest owners in the Other category adopted harvesting management practices at the highest rate, 89%, significantly above the other two categories of 65% for VFLEP and 66% for None. We attribute this to the flurry of specific Best Management Practice workshops and field days held by the Virginia Department of Forestry and Virginia Cooperative Extension throughout the 1990s and early 2000s. We suspect that many forest owners attended one or more of these targeted workshops, and not VFLEP, which placed them in the Other category. The two remaining practices, financial assistance and conservation easements, were not specific objectives of the original three workshops, however, these practices were mentioned. Neither of the practices had particularly high adoption rates, though 36% of forest owners in the Other category adopted financial assistance (Table 3). These lower rates led us to create two new workshops just focusing on these topics, as mentioned above.

The forest owners who attended VFLEP workshops did so between October, 1997 and February, 2004, a seven-year span. With the survey being distributed in the spring of 2007, this allowed for a roughly three- to ten-year time frame following workshop attendance, important because the adoption of practices may take several months to as much as 15 years (Rogers 2003). An important finding of this work is that both the development and use of a forest management plan and the use of professional technical assistance were significantly higher for the group that attended VFLEP workshops. These were key educational objectives, since these two practices are often related to improved forest management (Jones *et al.* 2001). Indeed, the development and use of a management plan is central to the access of certification systems for sustainable forest management, such as the Forest Stewardship Council, Sustainable Forestry Initiative, and American Tree Farm System (Rickenbach 2002). This may be an indicator that in the future more recent VFLEP participants will also adopt at a higher rate.

Evaluating Individual Workshops

Looking at the adoption rates for forest owners who attended specific workshops reveals fairly high adoption rates. For example, forest owners who attended a wildlife management workshop adopted wildlife management practices at a rate of 82%. Those who attended a woodland management workshop adopted one or more woodland management practices at a rate of 97%. Those who attended a harvesting and marketing workshop adopted best management practices at a rate of 62%. Attendees at any of the workshops adopted written management plans at a rate of 41% and used technical assistance at a rate of 76%. These are considerably higher than the national average of 4% for management plans and 14% for technical assistance (Butler 2008). Additionally, the reinforcing value of attending multiple workshops is evident in Fig. 1, which shows the increasing adoption rate for both management plans and technical assistance as forest owners attend additional workshops. In both cases, the highest adoption rate occurred when forest owners attended all three workshops.

Summary and Conclusions

This paper clearly associates the adoption of a variety of sustainable forest management practices to participation in forestry extension programs. There are significant relationships between adoption and participation in educational programs for all of the seven categories studied. Two of the categories can also be considered as preliminary steps to additional activity and adoption in the future: technical assistance and management plan. Forest owners frequently cite technical assistance as a desirable and important step toward managing their forests (West *et al.* 1988, Kilgore *et al.* 2007). Rasamoelina *et al.* (2010) determined that technical assistance, management plan, and economic motivation were the three most significant variables in predicting the probability that a given forest owner would adopt SFM practices.

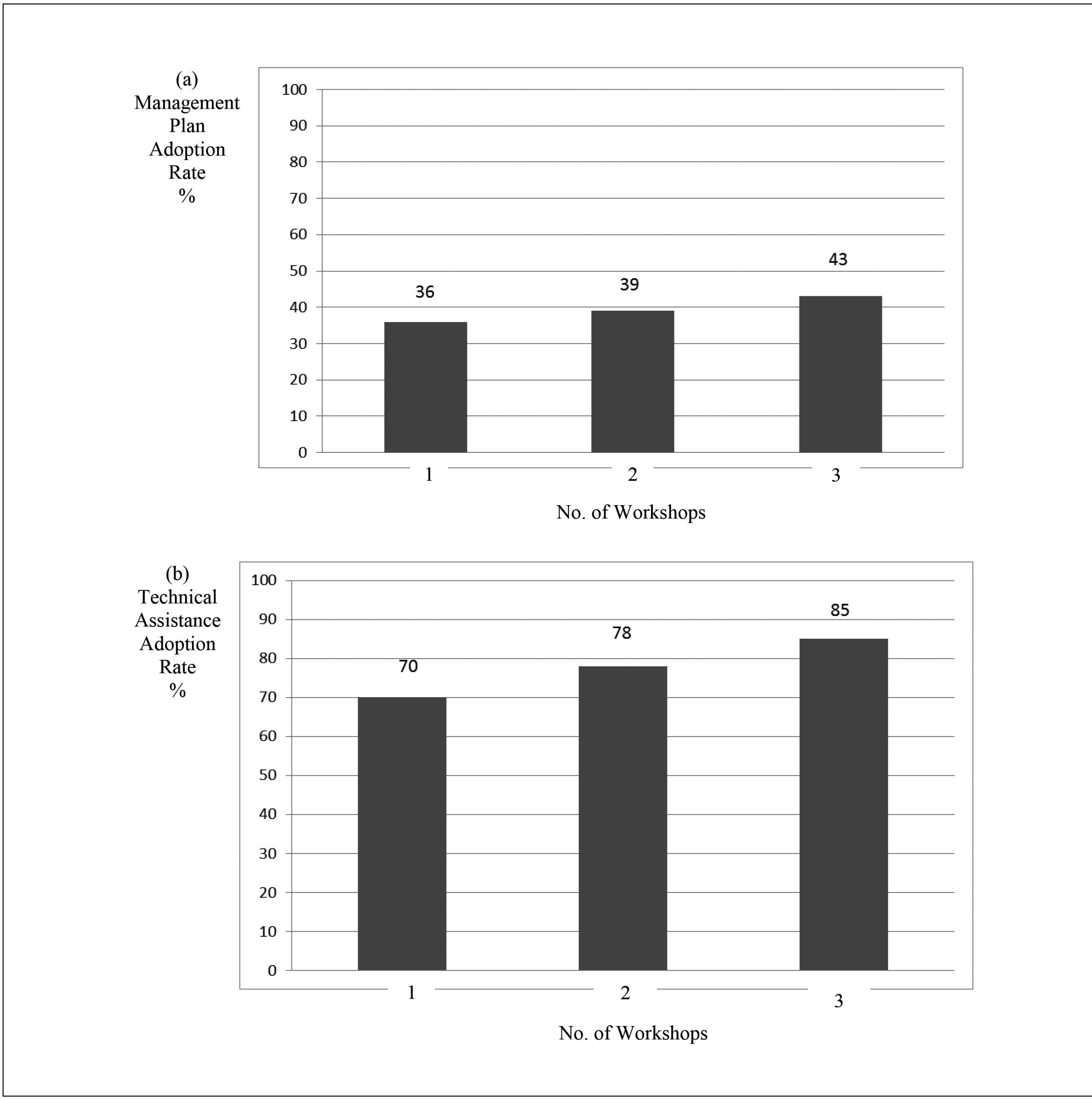

Fig. 1. Relationship between number of workshops attended and adoption of forest management plans (**a**) and technical assistance (**b**).

An important point to note is that the educational programs discussed in this paper were designed to appeal to forest owners with a variety of interests and motivations. It has long been known that the forest owner community at large consists of groups of individuals with varying motivations for owning land, varying interests in managing their land, and varying objectives (Marty *et al.* 1988, Rosen and Kaiser 1988, Salmon *et al.* 2006, Butler *et al.* 2007). The workshops offered through VFLEP were targeted to owners with general interests in woodland management, interests in wildlife, and economic interests focusing on timber. This no doubt resulted in a broader attendance at these educational programs, and perhaps also a higher rate of adoption.

It is recognized that in the future much of the private forest land in the U.S. will be turning over to a new generation of owners, and in fact, this may already be happening as surveys have shown that parcel sizes are decreasing, a reflection of land subdivisions (Sampson 2000, Butler 2008). This will result in yet a new audience of forest owners that may have a different set of values and motivations than the previous generation, and may also have different learning styles and preferred modes of learning (Kendra and Hull 2005, Mater 2007). Clearly, extension education programs will need to evolve to meet these challenges.

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Increasing the effectiveness of knowledge transfer activities and training of the forestry workforce with marteloscopes

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ABSTRACT

Sample plots of various sizes and forms are put in place to describe and monitor trees, stands or forest characteristics. The intent is usually to provide the basis for measuring and understanding the forest. Marteloscopes, by contrast, are large plots designed for tree marking simulations, set up with human beings as the main focus: they are used for knowledge transfer activities, training of various categories of forestry workers, and even for the study of human tree selection behaviors. This distinctive type of permanent plot is relatively new and unfamiliar to North America's forestry professionals. In this paper, we provide a working definition of marteloscopes and demonstrate how they can significantly improve knowledge exchange and learning experiences, notably for complex decisions on partial cutting treatments. Potential uses of marteloscopes, their benefits as well as some of the challenges they bring are discussed in the presentation of selected examples from Canada, the United States and Italy. These examples cover uses by research agencies, universities and non-profit organizations. Finally, we discuss ongoing developments for marteloscopes, the standardization of protocols and the potential benefits of linking marteloscopes into an international network, as more of them are put in place in diverse and unique forest settings.

Keywords: permanent plots; tree marking; human behavior; tree classification; tree selection; selection harvest; partial harvest; selection cutting

RÉSUMÉ

En général, on établit des parcelles échantillons de tailles et de formes différentes pour décrire et suivre les caractéristiques des arbres, des peuplements et des forêts. L'objectif est habituellement de fournir les éléments de base pour mesurer et comprendre la forêt. Les martelodromes, par contre, consistent en de grandes parcelles conçues pour des exercices de marquage d'arbre orientées sur le volet humain de l'exercice : ils servent aux activités de transfert technologique, de formation de diverses catégories de travailleurs forestiers et même pour étudier comment les humains font la sélection des arbres. Ce type particulier de parcelles permanentes est relativement nouveau et peu connu des forestiers professionnels en Amérique du Nord. Cet article donne une définition pratique des martelodromes et illustre comment ils peuvent réellement améliorer l'échange des connaissances et les expériences d'apprentissage, notamment pour les décisions complexes liées aux coupes partielles. Au moyen d'exemples provenant du Canada, des États-Unis et de l'Italie, l'article fait le tour des applications potentielles des martellodromes ainsi que des avantages et des défis qui s'y rattachent. Ces exemples illustrent des applications dans le domaine de la recherche, mais aussi pour les universités et les organisations sans but lucratif. Finalement, nous analysons des progrès en cours avec les martelodromes, la standardisation des protocoles et les avantages qu'il y aurait à intégrer les martelodromes en un réseau international, à mesure qu'il s'en établira de nouveaux dans des environnements forestiers différents et uniques.

Mots clés : parcelles permanentes, marquage des arbres, comportement humain, classification des arbres, sélection des arbres, coupe partielle, coupe de jardinage

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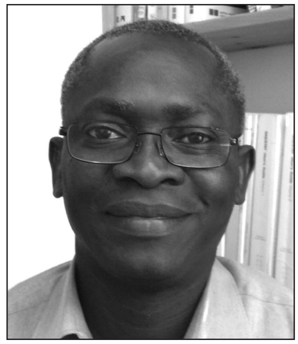

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Introduction

The basic training of many forestry professionals starts with some dendrology and forest mensuration courses, then follows, to various degrees, concepts of biology and ecology to build-up the knowledge necessary to effectively design forest inventories, silvicultural prescriptions and management plans that can steer stands of trees towards specific goals, given the complexities of the ecosystem. The ability to properly describe the state of the forest and to monitor its evolution has been, and still is, receiving much attention. Perfect and complete information on the whole forested area being impractical and unrealistic, sample plots in conjunction with data acquisition tools are commonly used to describe and monitor tree, stand and forest characteristics, making up the basis for informed forest management. Thus, forestry professionals are trained to set up plots and to properly identify important characteristics within those plots.

In recent times, adverse public reaction to management by clear-cut and the increasing popularity of Continuous Cover Forestry management (Pommerening and Murphy 2004, Pukkala and von Gadow 2012,) and of silvicultural systems whereby the forest canopy is maintained at one or more levels without clear felling (Franklin *et al.* 1997, Ruel *et al.* 2007, Raymond *et al.* 2009) make the different variants of partial cutting preferred practices in many circumstances. Thus, much effort and attention are put towards ensuring that standards are set and applied to describe, measure and classify trees. Nonetheless, it is increasingly recognized that it is very difficult and unlikely to have all forestry professionals agree on which trees to harvest when applying a partial cut. This holds true even when they have a common description of the characteristics of the trees that surround them and pursue the same outcome (Spinelli *et al.* 2016, Vítková *et al.* 2016). Tree selection happens to be one of the most complex tasks in forestry. Selecting a tree for removal not only determines the outcome of the current harvest, but also greatly influences future harvests through its effects on regeneration, available growing space, vigour, and composition of the residual stand. Usually, forestry professionals can agree on the present state and characteristics of a forest stand, the desired future state and goals for that stand, and the harvest prescription to manage the stand to reach the given goals, but they often disagree about the actual trees to select when trying to apply that prescription. This can present challenges between those who select trees and those who verify the quality of work performed. This also raises concerns of coherence between what actually occurs and what is modelled in long-term plans. Because wood supply is increasingly becoming constrained in quantity and quality, making the right decisions when selecting trees is crucial.

Research suggests that this difficulty in agreeing on tree selection is just as significant between professional foresters as between loggers (Spinelli *et al.* 2016). On the other hand, expertise (experience and training) in selecting trees according to a given set of rules in a certain type of forest seems to be a driver of consistency in outcomes (Vítková *et al.* 2016). Practice in eastern Canada suggests that experienced loggers and harvester operators, selecting trees as part of their job, can do just as good a job as certified tree markers in their context (Girard 2008a, 2008b). Hence, if increased agreement is sought-after, it appears that tree selection requires a different, more adapted, training than that of being able to properly characterize trees and project their evolution in relation with the desired outcome.

Such observations, added to the high cost of tree marking prior to selective cutting (Cimon-Morin *et al.* 2010), have resulted in many jurisdictions questioning the actual benefits of tree marking. Many regions, from Europe to North America, are seriously considering different approaches to increasing the tree selection skills of their workforce, and considering transferring that responsibility to loggers and harvest machines operators. Increasing focus is thus being put on properly training the loggers and harvest machines operators. In parallel, new control mechanisms are developed and tested to ensure the quality of the tree selection work performed as *per* the objectives of the landowner.

Experimental forests, dedicated to both research and training, are commonly found throughout the world. Most forestry schools and training facilities have dedicated training forests but the infrastructure is mostly built and used to demonstrate how the forest ecosystem works (focus on the forest rather than on the humans…). Training plots are integral parts of those training forests. However, the purpose of the majority of those plots seems to be dedicated to characterizing and monitoring trees, stands or forest characteristics, or to learning how to properly assess and monitor those characteristics. Very few are designed or dedicated to train for tree selection skills and professional proficiency.

While concepts of proper selective cuttings have been promoted for centuries, it is only in recent decades, notably with the increasing popularity of continuous cover forestry promoted by groups such as Pro Silva (Pro Silva 2012) in Europe and increasingly in North America, that permanent plots dedicated specifically to training for tree selection while simultaneously integrating biodiversity aspects (Schuck *et al.* 2016) have started to appear in significant numbers. These permanent plots are increasingly being referred to as "marteloscopes", but this term remains mostly unknown to the forestry community, especially outside of Europe. Unfortunately, no official definition of marteloscopes could be found in the scientific literature and it is not a word commonly found in forestry dictionaries or textbooks. A basic search for the term "marteloscope" in some of the major academic database (i.e., AGRICOLA; IngentaConnect; CAB Direct; JSTOR; ScienceDirect) did not return any positive results. However, in the web pages and non-peer reviewed literature consulted, a certain consensus on its meaning seems evident. The term marteloscope is most often defined as " … *1-hectare large, rectangular forest site where all trees are numbered, mapped and recorded. In combination with a software tool, they are used for silvicultural training*" (Schuck *et al.* 2016). Variants in size and shape of marteloscopes are common, and the software tool often offers the ability to simulate future conditions in addition to provide a synthesis of the immediate outcome of virtual tree selection exercises. Limited information can be found on characteristics deemed important for plots dedicated to tree selection training and no official standards for installing such plots could be found. Nonetheless, the protocols used by various organisations that installed marteloscopes is usually well documented (Ammann and Junod 2012, Soucy 2014, Integrate+ 2015).

The goal of this paper is to provide a working definition of marteloscopes in the scientific literature as being permanent plots whose main focus are humans: for knowledge transfer activities, the training of various categories of forestry workers, and even the study of human tree selection behaviors. We demonstrate with examples and argue how marteloscopes can significantly improve knowledge exchange and learning experiences. The potential uses of marteloscopes, their benefits as well as some of the challenges they bring are discussed in the presentation of selected examples of marteloscopes from different regions of Europe and North America. Finally, we discuss ongoing developments for marteloscopes, the standardization of protocols and the potential benefits of linking marteloscopes into an international network as more of them are put in place in diverse and unique forest conditions.

Marteloscope: More than a Permanent Plot

A marteloscope is commonly presented as an area of forest where all the trees are mapped, numbered, measured and classified for various values such as monetary, quantity and quality of wood, aesthetics, cultural and historical attributes, vigor, wildlife, ecological and biodiversity attributes. At first glance, the various presentations of marteloscopes found seemed to direct the term to the physical plot itself. However, because marteloscopes are presented with a clear focus on human tree selection behavior, all descriptions also presented some "apparatus" (i.e., a software) specifically adapted to the plot to summarize and visualize the effects of the virtual tree selection on stand characteristics. The European Forest Institute through their Integrate+ project produced a series of booklets that illustrates well some of the possibilities of such tools (Schuck *et al.* 2016). Some of those software applications also assess and analyse certain human behavior characteristics such as the level of agreement between participants and summary of reasons expressed for protecting or for cutting trees (Lussier and Fontaine 2013, P. Junod, forest engineer, Centre de compétence en silviculture, Lyss, Switzerland; pers. comm., May 2014). From these observations, we suggest that the term marteloscope refer to the combination of a permanent plot (i.e., forest area) with a means to summarize and visualize the outcomes of a virtual tree selection within that plot.

From experience conducting various activities related to tree selection, a few characteristics seem important for a permanent plot to be adapted for tree selection training. Most notably, the area covered by the plot should be sufficient for a realistic (from the point of view of participants) tree marking exercise. One element that seems to raise questions for participants is in determining how to deal with the effect of out-of-plot trees on the decision to select within plot trees that are near the edge. Thus, the area should be large enough to limit that effect. It should also be large enough to allow participants to reach a level of familiarity with the forest conditions and with the selection prescription. A few marteloscopes in Canada have been set up with an extra 0.2 hectare section dedicated for familiarization of participants with the concept, the requested prescription and with the forms they have to fill. This "training" portion of the marteloscope allows participants to raise questions on their understanding of the protocol, and allows trainers to validate that participants understood well the exercise. Marteloscopes currently in place vary in size from 0.3 ha to 2.5 ha, with the most common being 1 ha (Soucy 2014, CCS 2016, Integrate+ 2016).

In terms of stand types (composition, structure, age) where marteloscopes are installed, there are no "wrong" types, but for obvious reasons, existing marteloscopes are concentrated in uneven-aged stands destined for continuous cover management and in even-aged stands that are being considered for selective thinning. The driver for selecting a possible site should be the training objectives and the silviculture questions or problems to be tackled (Amman and Junod 2012).

The tree and stand data that needs to be available from each plot depends on the tree selection prescriptions that will be used and on the criteria needed to assess the participants. The data should allow analysis of the intensity and nature of the tree selection made by each participant. Typically, tree species and diameter are common to all. Other measures such as expected product recovery, tree vigor, habitat characteristics are also common, but usually highly dependent on the mission (timber production, multifunctional forestry or conservation) of the organization that installed the marteloscope. The focus of the data and models used are most often related to growth and yield of wood, but examples can be found of marteloscopes focusing on other forest values such as ecological functions (Pro Silva France 2003) wildlife habitat and biodiversity (Schuck *et al.* 2016) or used to introduce concepts such as fire management and protection from falling rocks (Gineste 2010). Hence, data on plants and components of the ecosystem other than the trees give the opportunity to simulate and accurately project the effects of different tree management approaches or scenarios on the whole ecosystem.

When marteloscopes are to be used to analyse tree selection behavior, data from participants are also required. Typically, information of each participant's profession, training and level of experience are gathered. In addition to providing the list of trees selected, participants are also commonly asked to report on the reasons that motivated their choices (such as tree health, competition, regeneration, economics). Reasons for selecting trees to be protected can be just as informative as reasons for selection trees to be harvested (Pro Silva France 1995).

The software associated with the plots commonly allows visualizing tree maps and summarizing various stand characteristics. It will permit the analysis, in near real-time, of the performance of each tree selection participant. Typically, as each participant's selection is entered into the application, with or without indication of reasons why it was selected, a summary of results and comparisons to other participants' selections can be visualized. But most importantly, many of the software developed are linked to tree and stand growth models, allowing immediate simulation and presentation of how the residual stand is expected to respond following the harvest of the selected trees, without having to wait for decades of actual growth response. This allows participants to challenge their beliefs against the current state of knowledge within a short period of time, and provides a unique opportunity for participants to assess, discuss and adapt their approaches and techniques.

In essence, marteloscopes have the following characteristics rendering them suited for human tree selection behavior analysis:

1. Defined area sufficiently large to allow for a representative tree marking exercise;
   a. Represents the extent of stand conditions with its natural diversity
   b. Allows participants to learn how to use the marteloscope
   c. Allows participants to understand the prescription that is requested
   d. Allows participants to get used to filling the required forms
   e. Contains a number of trees large enough to permit participants to repeat the exercise, without fear that they remember every tree and prior decisions that they made
2. Complete information on every pertinent variable on every tree;
3. Forms or interface to capture data on participants and their tree selections;
   a. List of trees selected for removal
   b. Optionally:
      – List of trees to be protected
      – Reasons for removal or protection
      – Profession; level of training; level of experience of participants
4. Interactive platform to summarize and analyse outcomes of virtual tree selections;
   a. Current conditions
   b. Immediate outcomes of tree selection (removals and residuals)
   c. Optionally, future outcomes

Readers should be aware that other kinds of training sites exist that do not fit the definition of a marteloscope. A good example would be "martelodromes" common in the province of Québec where a number of trees are measured and classified for the purpose of training and certifying tree markers (MFFPQ 2016). Contrary to marteloscopes, these training sites do not cover a defined area and not all trees are measured, hence a constraint to per hectare calculations and whole stand summaries. It is rather a group of trees used to ensure that workers can recognize defects, harvest priority, acceptable growing stock, hazard trees, wildlife trees and classify trees appropriately, but not usable to train for the complete process of tree selection. It is important to recognize that in selection cuttings, the decision to harvest or not a given tree is related to its surrounding trees (Arbogast 1957, OMNR 2004, Bruciamacchi *et al.* 2005).

Origins and Proliferation of Marteloscopes

While we could not find an official origin of the term "marteloscope", the word is likely of French origin combining "martelage" (i.e., the act of selecting and marking a tree) and "scope" (i.e., an apparatus for visualising something). Permanent plots referred to as "marteloscopes" seem to have started to appear in many European countries in the 1990s and early 2000s. Marteloscopes can now be found in many European countries such as France (Génot 2009), the United Kingdom (Poore 2011), Belgium (Baar and Collard 2007), Italy (Spinelli *et al.* 2016), Switzerland (CCS 2016), and Germany (Integrate+ 2016). Pommerening *et al.* (2015) attributes the origins of marteloscopes in Germany to the unexpected product of a research project led by Professor Klaus von Gadow that investigated the tree selection behavior of forest managers and machine operators. The potential of the research site for teaching and training was recognized and the term "marteloscope" was subsequently attributed to brand this type of research plot to which a tree selection analysis tool is attached. Since then, this type of plot has gained in popularity and has recently begun to appear in North America. Such plots are found under various names and appellations, ranging from "permanent plots", "training plots", "tree marking training plots", "martelodromes", to variants of the word "marteloscope" ("martelloscope", "martéloscope", "M-scopes"). It is only recently that the term has started to appear in peer-reviewed scientific literature (e.g., Bruciamacchie *et al.* 2005, Burrus and Mourey 2011, Spinelli *et al.* 2016, Vítková *et al.* 2016).

The origin of marteloscopes is obscure. They may have been already in use in Europe before the first mentions made by scientific authors in the 1990s. It is certain that the agency for the development of agriculture and forestry (ERSAF) in Lombardy (northern Italy) installed three marteloscopes before 2000, and it has been using these marteloscopes for training purposes since then. In fact, over the years the number of regional marteloscopes has increased to seven, in order to cover a range of silvicultural cases. Region Lombardy has integrated their marteloscopes into a life-long training project named "Forestry Education" with the purpose of extending forestry knowledge to other parties than just the Regional staff. Targeted stakeholders include certified forestry consultants, students and landowners. On the same line, the Forestry Service of Bolzano Province (north-eastern Italy) began installing their marteloscopes in 2005 using a standardized protocol developed in conjunction with the University of Vienna. To date, the number of provincial marteloscopes has grown to 18, and they are used mainly for training Provincial staff, although some events are opened to other stakeholders (Maistrelli 2014). The rapidly increasing popularity of European marteloscopes is directly related to changes in current silvicultural practices, aimed at integrating additional new goals to the conventional ones of soil protection and wood production. Promoting biodiversity is probably the strongest motivation for using marteloscopes because special training is necessary for the correct application of the new silvicultural guidelines. For this reason, marteloscopes played a prominent role in the PProSpot project, completed in 2013 (Life+ PProSpoT 2014). This project was funded by the European Union within the scope of the LIFE programme (http://ec.europa.eu/environment/life/), and had the goal of supporting new silvicultural practices aimed at preserving sporadic species. To this purpose, three new marteloscopes were established in the hardwood forests of Central Italy, where they are still being used for training (Torregiani *et al.* 2012). The correct application of silvicultural guidelines aimed at increasing biodiversity is also the goal of an even larger European project, known as Integrate+ (*http://www.integrateplus.org*). The project is coordinated by the European Forestry Institute (EFI) with the financial support of the German Ministry for Food and Agriculture (BMEL), and represents the first attempt at integrating a wide network of 29 marteloscopes across nine countries. Following this example, eight vocational schools from Belgium, Finland, France, Italy and Spain joined into a new initiative appropriately called "hammer-project" (*http://www.hammer-project.eu*). The project is funded by the European Union within the scope of the ERASMUS program (*http://www.erasmusprogramme.com/*) and is specifically designed to support the common educational needs of the Union. Project partners have established their respective marteloscopes according to common guidelines, and they use these marteloscopes for training their students on an exchange basis with grants supporting the participation of 96 students among participating schools. In essence, the relevance of marteloscopes in Europe has grown very rapidly and the trend is towards cross-country integration, which may soon lead to standardization. These same trends are now showing within the ProSilva network, which is making increasing use of marteloscopes in its activities. Another example of the proliferation of marteloscopes is the steadily growing network of marteloscopes maintained by the Centre de compétence en silviculture in Switzerland that has reached 28 sites in 2016 (CCS 2016)

The Pro Silva network has supporters in North America that "imported" the idea of using marteloscopes to improve training and knowledge transfer on continuous cover forestry concepts. Marteloscopes started to appear around 2010 in the New England states (USA), either associated with universities or with a forestry foundation. Similarly, seven marteloscopes were installed in New-Brunswick by the University of Moncton's forestry school between 2012 and 2015. These independent initiatives raise an opportunity to link them, possibly leading to intercontinental networking and standardization.

From our search for the term marteloscope, we have identified close to 100 reported marteloscopes in Europe and North America. Each marteloscope required extensive resources to put in place (both the physical plot and the complementary software). It is surprising that the term has yet to become more common in the scientific literature.

Marteloscopes to Increase Training Effectiveness

Unless a systematic harvest is performed, the act of selecting trees to harvest requires a complex decision-making process that is not yet well understood, resulting in discrepancies between expectations from the designer of a partial harvest prescription and the actual harvested stems (Brassard *et al.* 2003, Meadow and Skojac 2008). Such discrepancies and inconsistencies between the intent and outcome of a partial harvest clearly indicate that the training of the forestry workforce for tree selection is less than perfect and, at best, average.

Effectiveness of training or knowledge transfer activities can be summarized as the level of success in transmitting intended knowledge and competency to the participants. To do so, it is important that training activities permit different interactions and allow participants to validate how they perform relative to their perception and relative to the goal of the exercise. Validating one's own perception with reality is not trivial. Marteloscopes offer this possibility. Pommerening *et al.* (2015) give an example of a worker who was confident of having marked trees according to a crown thinning prescription while results indicated otherwise, to the surprise of the worker. Similarly, during a tree marking exercise in the Gounamitz marteloscope in Canada where over 100 participants tested their tree marking skills, some of the long-time lead developers of a tree classification system for vigor tried to mark trees to increase the average vigor of the residual stand while respecting operational constraints imposed (width and location of extraction trails to be put in, expected type and size of harvesting equipment). They were dismayed when results indicated that their actual selections were causing a degradation of average vigor. Not believing the results generated by the marteloscope software, they returned into the plot only to realize that they had failed to reach prescribed objectives because of numerous field constraints that "forced" them into willingly selecting some of the most vigorous trees and leaving behind less than ideal ones. Perception is often far from the reality but without any confrontation there is little to force one's perception to evolve. Likewise, being the one making the tree selection gives a totally different perspective to that of an outside critic that analyses punctually the acceptability of selection decisions made by someone else.

In the same line of thought, it can be just as useful to allow the comparison of individual participants to the rest of a group. Allowing trainers to see how participants behave contributes to engaging in constructive discussions and suggesting corrective actions to improve participants' competencies.

Tree selection is a multi-stage process that, in many cases includes: i) the identification of attributes such as defects (mechanical, pathological…); ii) the assessment of the effects of the identified attributes on future tree and stand yields; and, iii) the hierarchy of attributes and their severity leading to the identification of which trees, relative to their neighbouring trees, should be cut to improve a forest stand. Though attributes like types of defects and classes are usually well-defined, the classification itself remains based on qualitative appreciations. Consequently, two professional foresters could look at the same tree, agree on types of defects but fail to agree on the hierarchy of the types of defects and/or the severity of those defects. Therefore their tree selection results may diverge. The marteloscope is an appropriate setting for professional foresters working in a region to standardize interpretations of qualitative criteria, to set baselines and to agree upon the interpretation of observations of diverse kinds needed to make tree selection. The expected outcome is that, given a silvicultural objective (i.e., prescription), there would be less and less disagreement among professionals in the assessment of forest stands and in decision-making.

Training aid for forestry schools

Forest management is an exercise in decision-making, of which actual results can only be seen and assessed after many years or decades as forest growth is slow. Thus training the forestry workforce that makes those decisions is not to be approached lightly. In every country where there is a minimum of forest cover, forestry schools are essential parts of the education system. In such schools, curricula are designed to teach trainees how to make tree selection in forest stands to achieve various silvicultural objectives. Natural forest stands and particularly hardwood ones are very diverse and complex in composition, structure (horizontal as well as vertical) and state (i.e., vigor).

From the viewpoint of many forestry schools, a marteloscope's primary purpose is to serve as a teaching aid for demonstration and hands-on training of tree selection concepts (Junod 2010). Explanations of silvicultural concepts and how to apply them to the tree selection in a selective cut are covered in textbooks. However, one needs to acknowledge the limits of textbooks to effectively convey the inherent complexity of natural ecosystems like forests. Marteloscopes allow the transition between the textbook representation and the complexity of the real stand. At the same time, it offers the means to ensure that trainees have a common understanding of tree and stand attributes as well as the concepts that were presented in class.

Moreover, the ability to quickly run trainees' selection results into a growth-and-yield model or any other accompanying software allows students to envision the future stand and critically revisit their tree selection decisions. The marteloscope thereby enhances interactions between students and stimulates learning. In addition, the setting allows a trainee to try out various approaches/scenario of cuts, visualize and compare their results and draw lessons on decision-making in situations of conflicting approaches.

The Université de Moncton's forestry school has been using marteloscopes for three years in an attempt to improve the transition from knowledge of theoretical concepts into field competencies. The first benefit of bringing students into 1.2 ha permanent plots was the ability for teachers to quickly adjust the amount of data available to students and to ensure they can focus on the learning objectives. Maps of the location of trees allow students to analyse spatial distribution of various tree attributes as well as to appreciate the distribution of their selection. The scale of the plot allows students to plan for and appreciate the impacts of extraction trails. It also made the exercise of identifying rare elements of conservation value (large cavity trees, vernal pools) more realistic within the tree marking exercise. The 1.2 ha plot size, however, proved to be too small for silvicultural treatments that would be heterogeneous. Therefore, students planning a patch selection cut or hybrid selection cut would place a very limited number of patches within the plot. This tended to restrict their freedom to prescribe and test original treatments. In an exercise where trees are marked using flagging tape, students get a unique point of view closer to the reality of tree markers or loggers, compared to simply noting tree numbers on a piece of paper or on an electronic form. Access to a spreadsheet directly in the field provides quick feedback making it possible to validate and adjust decisions, as the decision process they followed originally is still fresh in their minds. As a result, it was felt that students handed in reports that reflected a more complete understanding of the strategy they were proposing and of the criteria they used to mark trees. Students could also discuss the level of success of their proposition relative to the given tree marking goals. To date, the use of marteloscopes as a training aid proved to be a great addition to bring students to an in-depth appreciation of the nuances of tree selection and helps them realize some of the challenges induced by heterogeneous stand conditions and maintaining stand quality for future generations. Marteloscopes allow for easily adding complexity to the tree marking exercise simply by forcing the students to consider extra constraints such as limitations induced by the choice of a harvesting system. Marteloscopes also proved very useful to illustrate new or uncommon silvicultural treatments such as continuous cover irregular shelterwood (Raymond *et al.* 2009) for which demonstration plots would otherwise not be readily available in a given region.

Finally, it is important to recognize that the permanent nature of the plots does not necessarily mean that harvesting is prohibited. In fact, harvesting a marteloscope following a consensus on tree selection can actually help complete the learning experience. In Switzerland, the Centre de compétence en sylviculture uses a network of marteloscopes on an approximately 10-year cycle where each marteloscope is used for tree selection exercises for a two to three-year period before being harvested. The growth rate of their forest allows that they are back in that marteloscope five-seven years later to begin again tree marking while being able to observe the actual response to past harvests (P. Junod, forest engineer, Centre de compétence en silviculture; pers. comm., 2014).

Training aid for logging companies

Logging companies employ a number of professionals of various experiences and backgrounds to do the actual task of logging forest stands. It follows that training is required to ensure that loggers can produce consistent and acceptable results. Marteloscopes offer settings where loggers can be trained to the same criteria for assessing a forest stand and making tree selection decisions. This is of particular importance for forest professionals without formal training, common in many parts of the world, especially for manual workers and machine operators. A simple tree marking exercise can quickly eliminate discrepancies in the interpretations of the prescribed treatment.

It is also important to recognize that, while many workers may not have the scientific or professional vocabulary necessary to describe every characteristic of a tree, they can often easily learn how to recognise visually the presence of important characteristics. Training in a marteloscope setting allows workers and professionals with different "languages" to agree on a common understanding of important tree selection criteria.

Training aid for continuous education of the forestry workforce

Marteloscopes appear to be an ideal place for forestry professionals to gather and exchange experiences they acquire in their practice (Junod 2010). With marteloscopes installed in different types of forest ecosystems common to a region, a learning tour of forest professionals will give opportunities to those more acquainted with a particular type of stand to share their particular knowledge of that type with their peers. Such tours allow rich exchanges between professionals where similarities and differences among types of forest stand, objectives, scenarios, operations and outcomes will be discussed—and—most importantly, expected outcomes of differences may be simulated on the spot.

In 2013 as part of a field day of the fall meeting of the Canadian Woodlands Forum, more than 100 forestry professionals (i.e., loggers, landowners, foresters, mill managers) exchanged ideas on the challenges of managing hardwood forests in northwestern New Brunswick before being asked to participate in a tree marking exercise to validate their perceptions (Lussier and Fontaine 2013). The activity proved to be a major trigger of passionate discussions. It also triggered many new ideas and prompted the launch of a new applied research project while convincing some logging companies to seriously consider increasing the training of their workforce (Lussier and Fontaine 2013). Most participants started the activity not expecting to learn anything new or to find benefits. After having performed the exercise and having had time to review the actual results of their selections, the participants had a very different perspective of the potential of marteloscopes for improving their understanding of each situation. In the weeks following the exercise, participants were contacted individually to obtain feedback, comments and suggestions on how to improve the activity. Overall, the marteloscope with its visualization complement turned an otherwise ordinary field visit into an interactive and truly educational exercise. From there, many participants indicated that being paired with another participant made them realise how different they actually interpreted the significance of various attributes and raised awareness of multiple interpretation possibilities.

At a larger scale, initiatives such as the Hammer project cited previously contribute to developing a common understanding and operational consistency over large networks of professionals and across borders for those forest ecosystems that are shared by more than one Country/Region (e.g., alpine continuum, shared by Austria, France, Germany, Italy, Slovenia and Switzerland).

Marteloscopes for research

Marteloscopes also offer a powerful platform upon which different research themes related to tree selection may be explored. Pommerening *et al.* (2015) outlined a number of research questions that have yet to be considered but for which the settings of a marteloscope are particularly adapted. Following are a few examples of recent and current research conducted to illustrate this.

Human tree selection behavior

The debate about the suitability tree selection by logger and harvester operators lacks solid data upon which to ground the various arguments. Bringing together more than 60 certified foresters, loggers and agronomists in two marteloscopes in Italy, Spinelli *et al.* (2016) were able to document the level of agreement in trees selected between the different professional figures. They were able to show that little agreement existed in trees selected for harvest between the three groups of professionals, but also that even more disagreements existed between individuals within groups of professionals. On the other hand, some agreement by all participants seemed to appear when looking at future crop trees selected. Pommerening *et al.* (2015) reported similar trends in the level of agreement from groups of forest professionals in marteloscope settings in the United Kingdom. Considering that individually, professionals pursuing the same silvicultural objectives and placed in the same forest stand are likely to come up with different tree selections on different occasions, these observations suggest that tree marking has more to do with human decision-making and behaviour than with natural/forest science. As such, tree marking in marteloscopes (a permanent setting) offers an insight in human factors that govern tree selection.

Factors influencing the quality of tree selection

In hardwood stands in eastern Canada, Brassard *et al.* (2003) looked into factors that would influence the ability to perform tree marking (i.e., its productivity and the quality of the tree selection for a given prescription). Their results suggested the influence of factors such as the level of experience of the tree marker; however, the experimental setup was not ideal to control other confounding factors, which limited their ability to analyse the results and reach significant conclusions. In response, Auger (2015), proposed an experimental design based on a set of five marteloscopes to determine the influence of various factors presumed to influence the "quality" of tree selection, namely: level of training, years of experience, mobility (to assess the impact of harvester operators constrained to make tree selection from their cabin compared to tree markers or loggers who can walk around trees), and time available to make the decision. The implementation of that design with five workers to test the protocol demonstrated that marteloscopes provide a well-adapted experimental environment very similar to actual work conditions while also permitting for the control of factors external to the design.

Cost-benefit evaluation of different tree selection approaches

Eastern North America has two contrasting tree selection approaches widely applied throughout the territory in similar stands with similar management objectives: i) trained loggers and harvester operators perform tree selection as they proceed harvesting the stand (common practice in New Brunswick and Nova Scotia); ii) certified tree markers select and mark trees to be harvested prior to loggers entering the stand to perform the harvest (common to Québec and Ontario). Structural changes of the past decades in the forest industry has drastically reduced profitability and the state of the forest imposes pressures to ensure that optimum choices are made to ensure the continuity of the current level of harvest as well as minimizing operation costs. Case studies to document cost differences between the two approaches were successfully performed in real harvesting contexts (Girard 2008b, Roy 2009, FPInnovations Division Feric 2010). However, quantifying differences in benefits (i.e., quality of tree selection) was limited, partly because of study complexity and a lack of suitable physical settings for the study. We suggest that marteloscopes could offer an adequate setup to perform such tests and allow for drawing conclusions driven by actual observations rather than the current debate on concepts and on theoretical benefits of either approach. Similarly, others in Europe suggest that marteloscopes are particularly suited to evaluate the consequences, such as the cost of application of marking trees for different objectives, for example for timber versus biodiversity characteristics (Pro Silva France 2003).

Marteloscopes for extension and knowledge transfer

As forests are an important part of the environment, most people have a relatively strong opinion about their management, even if they do not have background knowledge of forestry. In the face of such widespread "uninformed" opinions on their profession, professionals can use or adapt marteloscopes for knowledge transfer activities directed to a public with various levels of knowledge, experience or interest in forestry (Gineste 2010). As McKenney and Levine (2013) put it, "*few people outside of the forestry profession have had the chance to get a hands-on experience of tending a forest (…). A session with the marteloscope will give non-professionals a feel for the complex choices and unique skill sets that are required to manage forests*".

The importance of biodiversity and sustainable development has created both, a need for raising awareness of the general public, and touristic opportunities. Given the attributes of marteloscopes for transferring knowledge, it is not surprising to see one as a tourist attraction that serves the double purpose of retaining tourists in a region by providing a unique activity and provides a great opportunity to share knowledge on trees, forest and their management (Trossat 2009).

Woodlot owners

In rural forested regions, woodlot owners are often looking for advice from professionals with regard to the management of their lots. Marteloscopes are well adapted to conduct information sessions and workshops to educate woodlot owners. Unusual forestry concepts can be taught and different approaches/scenarios of management could be simulated with their results shown and the future forest derived from each scenario could be visualized by the woodlot owners. As the common expression goes, "seeing is believing". By allowing woodlot owners to test their own approach, marteloscopes can increase the odds that they will adopt better practices.

Policy- and decision-makers

Most often politicians enact laws that affect forest management and forestry professionals in their work without much knowledge of the forest and its complexity. In certain regions of Canada, local politicians at different levels of government and their representatives are regularly invited to take part in dedicated field tours. Marteloscopes could become part of such tours to help visualize the questions being discussed and the challenges of sustainable management. When time is limited, the interactive platform (i.e., the marteloscope software) can be used by itself to convey the expected consequences of different scenarios needing decision.

Interestingly, marteloscopes are also showing to be a relevant tool in shared forest governance schemes where the participation of a broad range of the population is called upon to play an active role in forest management (Quali Gouv 2012). With increased public participation in the forest management process, new needs for knowledge transfer are appearing; marteloscopes could likely play a prominent role.

Youth

Nowadays where extreme opinions tend to claim centre stage, outrageous claims made by news media about forest management and the forest industry are harmful to forest professionals. Marteloscopes can be a good tool for the education of students and help them contextualize the information that is brought to them by the sensationalist media. Tours with hands-on activities where the youth will implement management options and visualize the future forest deriving from their decisions will help them build their own informed opinions about the profession of forestry.

Ongoing Developments

A persisting challenge with forestry-related training is the distance that often needs to be travelled to reach the desired variety of forest settings. To improve on the trade-offs between classroom training and field exercises, different organizations are developing "virtual forests" and considering the potential of augmented reality in forestry. The idea is to offer realistic forest settings within a classroom context. As such, marteloscopes increasingly serve as the basis for such virtual forests. From the convenience of an office or classroom, one can "navigate" through a virtual representation of the stand, and sometimes even use an interface to select trees. The marteloscope database can easily be supplemented with data from various remote sensing technologies, such as terrestrial LIDAR, effectively increasing the possibilities of augmented reality. When performed on the basis of an actual marteloscope, participants can spend time performing exercises in the field, then pursue detailed analysis of their results and try to improve their performance using the virtual version of the marteloscope.

Limits of Marteloscopes

The examples above present the potential and benefits of marteloscopes. Just like everything else, they also have limitations, namely:

- Initial set-up of plot with the adaptation of a software can require extensive resources;
- Forest evolves with time hence particular characteristics are often ephemeral and require frequent update of data;
- There is not yet a common software or platform for sharing and analysing data of other marteloscopes;
- Data acquired in different marteloscopes may not follow a standard format or definition;
- It can be challenging to bring the participants, general public, politicians and decision-makers on site (Ginest 2010);
- Success of activities is highly dependent on the availability, competence and dynamism of the animator (Ginest 2010);
- Small scale limits effective consideration of certain silvicultural options; and,

- Software usually requires constant updates and revisions both to follow technological changes and evolution in the data and exercises.

Towards the Development of a Worldwide Network of Marteloscopes

Marteloscopes are proving to be a useful tool to increase the effectiveness of knowledge transfer and training activities, in addition to being a powerful research platform for human tree selection behavior. Their ability to allow people to validate their personal perception of their tree selection performance against current knowledge and understanding, as well as against the performance of others, is a solid starting point for constructive discussions based on transparent factual data. In consequence, the last decade saw a transition from marteloscopes being set-up as individual and independent initiatives, to networks of sites with a more standardized protocol and software. We do not foresee any reasons why further expansion of networks of marteloscopes would stop. As the New England Forestry Foundation puts it in its spring 2013 newsletter, "*marteloscopes can be expected to appear in a forest near you*" (**McKenney and Levine 2013**). Likewise, the term is likely to increasingly become part of the forestry vocabulary.

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Efficient forest fuel supply systems: Research, development and dissemination of knowledge in Sweden

by Maria Iwarsson Wide[1]

ABSTRACT

Efficient Forest Fuel Supply Systems (ESS) was run as a collaboration program, financed by the forestry sector, the energy sector, and the Swedish Energy Agency. The objective was to enable a long-term, sustainable and greatly increased use of forest fuel by supporting the development of a more efficient production system. The financial framework of ESS was SEK 130 million (approximately CA $ 19.5 million) over eight years, and the program supported approximately 150 research and development projects. Skogforsk administered the program, and was responsible for coordination and disseminating information to the stakeholders. A program board made formal decisions, and a fuel technology collaboration group helped to identify R&D areas. A project pilot was linked to each project to ensure that the focus was on sector needs and interests, and to help the project manager with relevant study objects, networks and updated information. In and around the program, valuable expertise and networks were built up in each sector and in research organisations, both nationally and internationally. Great emphasis was placed on practical demonstration, implementation and communication, in order to disseminate knowledge about new technology and methods and to influence attitudes toward forest fuel harvest. The forestry sector and its contractors gradually strengthened the supply system through improved skills, better organisation, and advanced equipment. The goals were largely attained, and practical aspects relating to forest fuel were implemented, incorporating many of the results.

Keywords: primary forest fuel harvest and handling, cooperation program, bioenergy, knowledge implementation.

RÉSUMÉ

Le programme *Efficient Forest Fuel Supply Systems-ESS* (Systèmes efficaces d'approvisionnement en combustible forestier) était un programme coopératif financé par le secteur forestier, le secteur de l'énergie et l'Agence énergétique de Suède. Il avait pour objectif de permettre une utilisation à long terme, durable et accrue de combustibles forestiers en favorisant la mise sur pied d'un système de production plus efficace. Le cadre financier d'ESS prévoyait des investissements totalisant 130 millions de couronnes suédoises (environ 19,5 millions de dollars canadiens) sur une période de 8 ans; il aura permis de soutenir près de 150 projets de recherche et de développement. Skogforsk a assuré la gestion du programme et avait la responsabilité de coordonner et de diffuser les renseignements aux différents partenaires. Les décisions stratégiques relevaient du bureau de direction alors qu'un groupe d'experts en technologie des combustibles s'occupait d'identifier les domaines de recherche et de développement. Il y avait un projet pilote rattaché à chaque système afin de mettre l'accent sur les intérêts et les besoins du secteur et pour fournir au gestionnaire du projet les objets de l'étude, les contacts utiles et les informations les plus à jour. L'ensemble du programme aura permis de développer une expertise et un réseau de contacts utiles dans chaque secteur et chez les organismes de recherche, tant à l'échelle nationale que sur la scène mondiale. L'accent a été mis principalement sur des démonstrations pratiques, le transfert technologique et les communications, de façon à faire circuler les connaissances rattachées aux nouvelles technologies et méthodes et pour modifier les attitudes sur la récolte de combustibles forestiers. Les entrepreneurs du secteur forestier ont graduellement fait évoluer le système d'approvisionnement grâce à de meilleures pratiques, une planification plus adéquate et de l'équipement moderne. Les objectifs du programme ont généralement été atteints et plusieurs résultats des travaux sur les combustibles forestiers ont été mis en œuvre dans les opérations.

Mots clés : récolte et transport des combustibles forestiers, programme coopératif, bioénergie, utilisation des connaissances

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Background

Forest fuel is playing an increasingly important role in our energy supply. A worldwide focus on the issue of climate change has resulted in both national and global forces calling for and promoting the transition to energy production based on renewable sources and bioenergy. In Sweden, one of the world's major forestry countries, bioenergy is almost synonymous with forest fuel.

Today, bioenergy accounts for approximately 130 TWh[2] or 35% of Swedish energy consumption, of which forest fuel, i.e., logging residues from felling and small trees from thinning activities, contributes 10–15 TWh. The goal to increase the proportion of biofuel in energy production is largely based on the potential to considerably increase the harvest of forest fuel. This potential is equivalent to an annual harvest of 40–60 TWh.

Today's production systems are the result of around 35 years of development and routine rationalisations. If forest fuel volumes are to be increased, the efficiency of production systems must be greatly improved. This can be done by integrating the forest fuel flows with other wood flows from the forest and in the systems of users/fuel processors and energy producers. This requires both technical innovation and development of control systems and decision support tools to improve utilisation of resources and yield value. Consequently, major and applied R&D initiatives are required in close collaboration with the relevant sectors. More intensive forest fuel harvest also increases the risks of impaired growth and undesirable environmental effects in our forests.

Efficient Forest Fuel Supply Systems (ESS)

The R&D program Efficient Forest Fuel Supply Systems (ESS) was run between 2007 and 2015 in the form of a broad collaboration between the Swedish Energy Agency and relevant sectors with the aim of developing forest fuel activities. The program was open for applications, and ESS thereby took the form of a network. Part of the ESS program involved training initiatives, and national expertise was built up and organised during the course of the program.

Vision

The vision was that forest fuel flows would be integrated with other raw material flows in relevant sectors, thereby ensuring an economically, environmentally and socially sustainable supply of forest fuel.

Objectives and aims

The objective was to help create the necessary technical and financial conditions to meet the increasing demand for forest-based fuel. By developing more efficient production systems for forest fuel, more of the potential can be realised in a long-term and sustainable way and in larger geographical areas than is the case today. This will enable forest fuel to make a greater contribution to fuel supply in different parts of the energy sector, and make it easier to ensure products meet the specific needs of different users. More efficient production systems will also assure long-term domestic wood supply to both the energy sector and forest industry. Reduced costs are seen as the main way of improving profitability. In the future, forest biomass can also be given a higher processing value, such as in the production of vehicle fuels, materials and chemicals.

Criteria for success

The results of the program were to:

- Increase knowledge, awareness and engagement regarding forest fuel issues among stakeholders and players, thereby generating greater consensus on wood supply in the sectors concerned;
- Promote the development of new technology, new applications, and new knowledge, thereby ensuring that more and cheaper forest fuel reaches the market;
- Increase the number of jobs and new enterprises, not least in rural areas;
- Broaden the academic expertise base in the forest fuel area; and,
- Produce and implement a good knowledge base to meet the needs of decision-makers and other players.

Funding and organisation

The program was funded by companies and organisations in the sectors concerned (forestry, transport and energy) by Skogforsk (Forest Research Institute of Sweden), and by the Swedish Energy Agency. Total funding was SEK 130 million, the equivalent of approximately SEK 17 million/year. The activities in the program were steered by a board comprising strategic leaders in the funding bodies and scientific experts. The board made formal decisions on which projects would receive support through the program.

A fuel technology collaboration group, comprising operative management personnel in participating companies, helped to identify development and research needs, and helped in the process from project concept to completed application. This group also served as a forum for discussion and sharing of experiences in development issues.

Project implementation

The program spanned both short- and long-term goals, and was strongly application- and problem-oriented. A broad approach was adopted. The program was led and administered by Skogforsk and was implemented in close collaboration with forest owners, forest fuel producers and users, and manufacturers of machines, equipment and systems. Skogforsk has a firm footing in the sectors concerned, thereby ensuring a strong financial base for the programme. Skogforsk also has a long tradition and experience of R&D in forest fuel.

[2]Energy production or consumption is often expressed as terawatt hours (TWh) for a given period that is often a calendar or financial year. One TWh is equivalent to a sustained power of approximately 114 megawatts for a period of one year.

The work was carried out in the form of clearly defined projects, studies and activities by both internal and external working groups and a mixture of these. In order to provide the program with the right mix of expertise, other research organisations were permitted to apply for project funding. Calls for applications for funding were made three to four times a year.

Communication plan and dissemination of results

The primary target groups were administrative and line staff working in forestry, fuel production and bioenergy use. The program activities were also aimed at suppliers of machines, equipment and systems, and instructors at various levels.

All results were presented in such a way that these target groups could access them in order to implement them as quickly as possible to provide practical benefit and added value. Results were presented through courses and conferences, films, online, and via less formal meetings, such as field studies, excursions, and seminars.

Skogforsk has a strong tradition of disseminating results and transferring knowledge. The projects in the program have been described and summarised in two syntheses, showing what was achieved in the R&D work. The reports also described how the results could improve the efficiency of forest fuel systems, as well as the current and expected role of forest fuel in the energy system.

Broad support was attained by involving stakeholders operatively in project planning and as project pilots in implementation. A clear indication of the strength in the program was the extensive implementation work that took place amongst the players. This meant a rapid turnover of results, and enabled implementation of efficiency improvements in practical operation. The great need and broad impact was shown by the scale of involvement and positive response during activities in which knowledge acquired during the program was disseminated.

The program involved approximately 150 projects. The overall conclusion is that there is great potential for considerably reducing system costs relating to forest fuel harvest. Efficiency can be improved throughout the production chain, through a combination of technical system development and planning support of various types.

The program has also helped to assure the long-term supply of skills and expertise by co-funding a number of doctoral student positions. This is of strategic importance because, for many years, the field has attracted limited attention in academia.

Skogforsk is involved in both Nordic and international networks. Within these networks, R&D activities have been coordinated to avoid duplication of work, to create a broad base of expertise, and to learn from one another. For example, the work has been synchronised with a major EU project, INFRES, in which Skogforsk participated. The program has also involved close collaboration and exchanges with Metla/LUKE (Finland), Norwegian Institute of Bioeconomy Research (Norway), IVALSA (Italy) and FPI (Canada). The collaboration has taken the form of joint projects and continual exchange of information and results.

Reflections and Results

The first phase of the ESS program, 2007–2011, was a dynamic period for forest fuel, and production grew strongly. New biofuel-based thermal plants were built and existing plants expanded, which increased demand for biofuel, 85% of which comes from the forest. Utilisation of primary forest fuel (logging residue, small trees, and stumps) increased during the first program period by approximately 50%, but through robust technology and method improvements, costs could be kept at an unchanged level. The forestry sector and its contractors gradually strengthened the supply system through improved skills, better organisation, and advanced equipment. The expansion of forest fuel production was a major reason why Sweden, already by the end of the first program period, reached the EU goal for renewable energy by 2020, the only country to do so.

However, during the second program period, 2011-2015, the positive development levelled off. Demand did not increase as expected for several reasons. Mild winters reduced the need for fuel, and a general economic downturn reduced the overall need for energy. However, even more significant was that the continued expansion of thermal plants started to involve other fuel types, particularly household waste, which is increasingly imported from other EU countries. In Sweden, many environment-related taxes and charges are levied on fossil fuels, which make biofuels competitive. During this period, the price of fossil fuels, including oil, fell dramatically, but there was no corresponding increase in the environmental charges and taxes, so biofuels have become less competitive. This also reduced the demand for wood chips.

The objective of the program was to improve the efficiency of forest fuel harvest with reduced costs, improved quality, and retained profitability for all players involved. Reduced costs and greater added value are seen as the main ways of improving profitability.

The program focused on developing existing and new technology for harvesting forest fuel. For example:

- The work on logging residue primarily involved improving quality, efficiency in forwarding, and decision support to prevent ground damage during harvesting.
- The work on stump harvest involved optimising the handling chain, and reducing ground impact and the amount of contaminants in the material.
- The work on small trees examined extraction in new types of stand, efficient thinning methods, and the potential of multi-tree handling under various conditions.
- A broad survey of comminution (particle size reduction) methods was carried out, with the aim of identifying the best technology in relation to different types of material and the quality required.
- The work on transport technology and logistics focused on developing and demonstrating longer and heavier vehicles, rail-road transports and efficient terminals, but also on how to manage and optimise transports.
- Measurement issues were a natural focal point in the second half of the program. A prioritised project area was to develop and evaluate the technologies and methods that are currently available or that could be developed.

- Pioneering work was initiated to define relevant assortments of forest fuel from a customer perspective.

A guiding principle in all projects and issues was to investigate what could be done to maximise quality in all stages of the handling chain.

Future challenges

There is great potential to increase harvest of primary forest fuel; today only one-third of the potential volume is utilised. However, the major fluctuations in demand make it difficult to encourage contractors and players to prioritise forest fuel activities; long-term and reasonably consistent demand is necessary. New market areas will be needed in the future.

Sceptics argue that using forest biomass should not be classified as sustainable use of forest resources, and that the climate benefit is doubtful. This will require communication and networking to influence on decision-makers.

Apart from reducing the total costs, the biggest challenge today is to improve quality aspects that will enable greater harvest and use of primary forest fuel. Here, we still see great potential. We must refine existing technologies and develop new ones for felling, handling and transport, and we must improve consistency, predictability and measurability of the fuel qualities required.

Structural and relational support for innovation – formal versus informal knowledge exchange mechanisms in forest-sector learning

by Karen Bayne[1,*], John Moore[2] and Simon Fielke[3]

ABSTRACT

In order to drive forest sector productivity, an emphasis has been placed on effectively transferring science knowledge to technical foresters. Having a communications plan and engaging the right stakeholders early can induce a rich learning environment that strengthens context, knowhow and ensures mechanisms are in place for knowledge to be transferred. Formalized structures such as reports and seminars have evolved to improve the science transfer process, but it appears that the key success factor in enhancing uptake and learning may require an environment that encourages relationship building, particularly trust building between parties in developing informal and formal relationships. Informal interactions, though not often acknowledged in business, foster the conditions conducive to good knowledge exchange – co-ordination, co-operation and communication. Enhancing conditions in which these three aspects grow can lead to increased social capital, changed paradigms and reduced business costs due to sharing of knowledge and resources. We posit a conceptual framework describing the role of formal and informal knowledge exchange mechanisms and introduce research innovation clusters as a means to promote forest sector engagement and informal relational support for learning.

Keywords: knowledge exchange, social capital, forestry, structural, relational, formal mechanisms, informal interaction, innovation cluster, interactive learning

RÉSUMÉ

Dans le but de stimuler la productivité du secteur forestier, on a cherché à renforcer le transfert efficace des connaissances scientifiques aux techniciens forestiers. Il suffit souvent d'établir un bon plan de communication et de mobiliser les bons partenaires dès le départ pour créer un milieu d'apprentissage stimulant qui renforce le contexte, le savoir-faire et assure la mise en place des mécanismes favorisant un transfert efficace des connaissances. Les structures formelles comme les rapports et les conférences ont changé, permettant ainsi d'améliorer le processus de transfert scientifique; mais il semble que le facteur déterminant pour améliorer l'apprentissage repose d'abord sur la mise en place d'un environnement favorable qui stimule le développement des relations entre les individus, particulièrement le renforcement de la confiance entre les parties avec l'établissement de relations formelles et informelles. Les interactions informelles, même si elles ne sont pas souvent reconnues au sein des entreprises, créent des conditions propices à un bon partage des connaissances : la coordination, la coopération et la communication. En améliorant les conditions propres à bonifier ces trois volets, il est dès lors possible d'accroître le capital social, de changer les paradigmes et de réduire les coûts pour l'entreprise grâce au partage des connaissances et des ressources. Nous proposons ici un cadre conceptuel qui décrit le rôle des mécanismes formels et informels d'échange de connaissances et nous introduisons des grappes d'innovation en recherche comme moyen de favoriser l'implication du secteur forestier et le support relationnel informel à l'apprentissage.

Mots clés : échange de connaissances, capital social, foresterie, mécanismes structuraux, relationnels et formels, interaction informelle, grappes d'innovation, apprentissage interactif

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Introduction

New Zealand has 1.7 million hectares of production forest estate, and exports $NZ 5.0 billion in forestry exports per annum, accounting for 3% of GDP, being New Zealand's third largest export sector (MPI 2016). During 2015, New Zealand exported over 17 million m^3 of logs, while the volume of logs processed domestically was approximately 13 million cubic meters (FOA 2016). Due to the large amounts of afforestation in the mid-1990s, New Zealand is projected to potentially have annual harvest volumes of approximately 36 million m^3 by 2022. Much of the increase in wood availability will come from small private forest growers (i.e., non-industrial private forests). The sector companies have traditionally aligned together into a number of separate industry associations for distinct advocacy along the value chain or for increased market access. The forest industry sees research investment as a critical component in realising the potential from the increased harvest through cost reductions and increased added-value processing (FOA 2012, Woodco 2012). To ensure the long-term future of the sector, forest growers also want to improve the economics of forest growing by increasing forest productivity and improving the uniformity and consistency of the trees in these future forests. It is therefore necessary to ensure investment within the science sector manifests into useful knowledge that can be quickly embedded into practical forest management. Knowledge producers and knowledge users require an exchange mechanism that encourages parties to learn and develop knowledge together in a useful and practical manner. The formal and accepted reason and motivation for exchanging knowledge is to take results from research and implement it in practice. The transferred knowledge should be: easy to understand by the receiver; applicable in its context; accessible—both physically, and intellectually (i.e., in layman's language and terminology) and in a knowledge receptacle that the user will find and refer to: relevant – interesting, credible and timely; undertaken by credible researchers (in the eyes of the users); and, cost efficient in terms of time (Becheikh *et al.* 2010). The knowledge therefore usually requires repackaging in terms of language and format to be useful and accessible to the user in a time-efficient manner. The ability to exchange knowledge more effectively is an important imperative for the sector in order to make targeted investments to gain and optimize the future forests.

Forming closer ties between forest industry and science in New Zealand, such that knowledge can be exchanged more effectively, has taken a number of forms over time. Future Forests Research (FFR) was established in 2007 to work in partnership with Scion (New Zealand Forest Research Institute Limited). The prime purpose was to improve the co-ordination of forest-growing sector research, particularly matching the needs of the industry members who joined up in the consortia with the research activities within Scion. The consortia replaced a former cooperative model, whereby industry members were members of certain cooperative research programs around different forest-growing objectives, e.g., stand growth modelling, site management, plantation management and different species.

In contrast to other New Zealand primary sectors, the forest sector has not had a research levy for funding, relying instead on voluntary co-funding for research from one of the forest sector associations or individual companies. This changed in 2013 when a compulsory levy on harvested wood material was passed into law under the Commodity Levies Act. This levy is administered by the Forest Growers Levy Trust, which now directs funding from monies collected at $NZ 0.27/tonne ($CA 0.26/tonne) in the first year and a maximum levy rate for the six year levy term of $NZ 0.30/tonne (FOA 2012). Through the Trust, the forest-growing sector has co-funded a new research program *Growing Confidence in Forestry's Future* (GCFF) which has as one of its objectives "*More efficient technology translation and dialogue between researchers and industry*" in recognition that "*overall levels of innovation will not only be determined by the performance of individual parties, but also by how they interact with each other*" (GCFF 2016). The program adopted the principles of co-innovation (Lee *et al.* 2012, Bitzer and Bijman 2015), which involves participation of multiple stakeholders to understand the problem, its causes and develop workable solutions. To facilitate co-innovation, four innovation clusters were established as a formal interactive mechanism for learning and co-development of knowledge. An innovation cluster includes members from various interest groups (e.g., corporate forestry staff members; government agencies; indigenous (iwi) representatives; research scientists) and others with a background in the specific cluster group focus. The purpose of the innovation clusters is to facilitate technology transfer — it focuses on interactive learning and knowledge sharing. The clusters do not have a governance role, and thus program administration and knowledge sharing are kept distinct from each other.

Systems of knowledge transfer

In a review of existing models which attempt to map knowledge transfer activities, Becheikh *et al.* (2010) outline four levels of interactivity between knowledge holders and practitioners in the transfer of knowledge, spanning a continuum between researcher-based approaches to a fully interactive model. The first more traditional approach focuses on the production of knowledge as a science push, results in a classic linear stage with iterative processes (RDD – research, development, diffusion). The criticisms of this level are the absence of knowledge exchange between actors in different disciplines and fields of expertise, along with an emphasis on university-created knowledge while practically ignoring the user context.

The opposite approach takes need of the user as primary and turns researchers into 'technicians' tasked with responding to these needs. This problem-solving approach has been criticized for placing sole emphasis on a 'user knows best' mind-set, whilst ignoring knowledge and expertise of the research community as having an understanding of what is required. This level also limits communications between user and researcher.

Linkage models ensure formal linkages exist between researcher and user and seek to integrate the concepts of the RDD and problem-solving approaches through a transfer agent. Guena and Muscio (2008) along with Santoro and Gopolakrishnan (2000) highlight the important part played by linkage agents in the transfer process, taking the dyadic transfer process between researchers and users to a triadic process, whereby the linkage agents discern the information and repackage the message so as to be better disseminated and implemented by user groups. While this level has the right intention, the formalized nature of interaction has been criticized for focusing on specific and exclusive mechanisms for engagement between researchers and users.

In contrast**,** *social interaction models* depend heavily on the diffusion stage through learning osmosis between researcher and user due to repeated interactions between numerous players involved in the transfer process. This level offers the most dynamic interaction between researcher and user, by placing equivalent importance on the knowledge transferred both ways.

There is an increasing impetus on focussing not on the transfer process amongst research and user alone, but the whole environment or system in which the transfer occurs (Edquist 1997, Rolings 1999). Spielman *et al.* (2009) state technological change is embedded within a "*larger, more complex system of interactions among diverse actors, organizational cultures and practices, learning behaviors and cycles, and rules and norms*" (pg 1). This system view recognizes that the development and implementation of 'science-for-impact' is the result of a process of networking, interactive learning and negotiation among a diverse group of people and that innovation is not just about adopting new technologies; it is an adaptive and responsive process.

This then begs the question of how the system in which knowledge exchanges occur in forestry science can enhance networking and build social capital, and how to facilitate the research-user environment to create stronger connectivity that enhances information flows and exchange of knowledge. Our research hypothesis is that innovation clusters are structural catalysts for co-learning that enhance co-operative exchanges of knowledge through developing relational capital. We outline a conceptual framework for enhancing the exchange of knowledge between science and industry, and test the effectiveness of the innovation cluster through a social network analysis.

Theoretical Framework

Social capital

Putnam (2001) described social capital in terms of "*connections among individuals - social networks and the norms of reciprocity and trustworthiness that arise from them*" (pg19), while Leana and Van Buren (1999) define social capital as "*…collective goal orientation and shared trust, which create value by facilitating successful collective action*" (pg 538). Social capital therefore consists of both the structural network and relationships built, the degree of shared trust and vision, and the knowledge that is mobilized through the network to create value. Nahapiet and Goshal (1998) explain social capital in three dimensions: A *structural* dimension that defines connectivity in terms of patterns of interactions and the network properties as a whole; A *cognitive* dimension that explains the development over time of shared language and behaviours and a common understanding by actors of how the network functions; A *relational* dimension that looks at the role of the individual within the network in terms of interpersonal relationships developed as a result of ongoing interaction, and where actor appeal and mutual interests along with trust are key relational elements.

Santoro and Gopalakrishnan (2000) state "*a firm is better able to absorb knowledge from external sources when it has created porous boundaries, when it scans for technology from a variety of sources, and when it maintains a continuous and consistent interaction with information sources*" (pg 300). Such recurring activity is more conducive to building relational channels (Ladd and Ward 2002), as the frequency and depth of human interactions leads to improved understanding of each other's business setting and needs.

Forming closer relations between the sciences and end users, while known to be mutually beneficial, is not often easy nor of high priority for either the research or industrial sectors (Kelli *et al.* 2013). Literature suggests that the motives for doing so include several factors:

- a joint imperative for the information to solve a pressing need and be quickly implemented (Ladd and Ward 2002, Simpson and Ashworth 2009),
- a requirement for access to important information (either data or results),
- perceived level of risk in technology development,
- or the uncertainty surrounding a known problem (Stock and Tatikonda 2000).

Knowledge transfer increases with a mutual understanding of the problem and leads to congruence around the research priorities and most possible solutions. A knowledge exchange environment where both parties have mutual respect for one another also increases the level of trust and reliability within the system, so that being honest, transparent and respectful in all interactions becomes an expectation amongst members. There is also more likelihood of both parties exploiting the joint social capital (networks built up over time) through informal forums, workshops and meetings to form the basis for more formal collaboration and agreement (Guena and Muscio 2008). Levin and Cross (2004) note that people prefer to learn from others than from documents, and stress the importance of the relationships between parties for social learning to occur, particularly in imparting tacit knowledge. Tacit knowledge deficit can only be bridged through dynamic interactions between actors within a supportive learning framework (network/ system) that facilitates tacit-explicit knowledge conversion (Nonaka 1994, Collins and Hitt 2006).

Building structural and relational capital through formal and informal mechanisms

The current drive of government funding in New Zealand towards greater collaboration between institutes and science fields hopes to both reduce the timeframe in which results can be implemented and to assist industry or public policy, while also creating an environment to promote social learning (MBIE 2015). In order to improve the speed of knowledge exchange, and make research results more relevant and transferable, a number of formal mechanisms have been employed.

A common approach to support user-researcher engagement is through steering or liaison groups, or communities of practice (CoP) to facilitate information exchange between science disciplines and across industries (pan-sector). Communities of Practice are an example of a social interaction model that formalizes and supports stakeholder networks to develop. The existence of these network connections in CoPs build social capital, and facilitate knowledge sharing (Wang and Noe 2010). Improving communications with a broad sector of influential 'fringe' actors in order to challenge the research and user paradigms, as well as informing the research of wider societal issues across a range of perspectives, can drive new research direction (Braund 1995). More formal structures such as industry-research consortia and establishing industry partnered 'centres of excellence' also support knowledge exchange, while focussing research on more tangible user-required outcomes (Fluckiger 2006). Engaging industrial champions to support the research, holding public meetings to discuss findings, as well as proactively engaging local media to report on progress can also assist in knowledge exchange and transfer of best practice to communities (Simpson and Ashworth 2009, Becheikh *et al.* 2010).

These more formalized engagement structures between users and researchers help to both contextualize the research, and increase knowhow by establishing better sectoral relations between the users and the scientists. Formal engagement involves a level of communication whereby the problem at hand can be given context by the shared understanding of existing knowledge and the environment in which the solution must sit. Knowledge and context are exchanged, with the knowledge transfer providing a facilitation role. An early communication plan and stakeholder analysis is critical to ensure the right level of informal/ formal engagement.

The ability to transfer tacit knowledge depends on close and regular associations that impart positive interpersonal dynamics (Tatikonda and Stock 2003, Collins and Hitt 2006). Because individuals and organizations do not usually have the complete picture and lack resource capability and capacity, they must integrate into networks with those who can contribute what they lack (Spielman *et al.* 2009). Membership of a network which allows for repeating and enduring relationships to develop increases the potential for knowledge to be exchanged (Inkpen and Tsang 2005). Providing supportive infrastructures, rules and norms that enhance the collective capacity to facilitate knowledge exchange can encourage actors to interact amongst themselves forming networks to share resources and expertise with one another (Kneller 2001).

Yli-Renko *et al.* (2001) found that external knowledge exchange depended on two key relational aspects: the level of social interaction occurring (frequency of interaction) and the links that members have to external knowledge that other members are not party to (number of network ties). Embedded (informal) relationships form from mutual interpersonal interests that drive reciprocity of information sharing forming a growth in trust (Wang and Noe 2010). Embedded relationships are resilient to changes in structural formation of a network and are moderated by norms in social behaviour (Nahapiet and Goshal 1998). The more informal interactions of scientists with industry can lead to enhanced research performance due to two-way knowledge transfer of ideas and the ability of researchers to adopt different perspectives, driving more innovative research approaches (Guena and Muscio 2008). Also of critical importance is the right mix of people who are contributing to discussions and informing the relationship (Ladd and Ward 2002, Simpson and Ashworth 2009). The effectiveness of creating an innovation network for knowledge exchange depends less on the quality and supply of the information and more on the systemic behaviours and practices which affect social learning and behaviours within organisations and between individuals (Spielman *et al.* 2009). Individual values, perceptions, previous experiences in knowledge transfer and priorities regarding the knowledge or technology being discussed are also known to impact the degree of transfer (Simpson and Ashworth 2009). Willingness to share knowledge also depends on the competitive value of the information and the perception of how the other party conforms to a norm of open science (Kneller 2001, Häussler *et al.* 2009, Häussler 2011).

People engage in knowledge sharing when there is a gain in social benefits, with individual attitude and organisational culture strong influencers of the degree of knowledge exchanged (Pacharapha and Ractham 2012). For effective inter-organisational interaction towards collaborative co-development, higher levels of organisational interaction skill dimensions (communication, co-ordination and co-operation) are required (Tatikonda and Stock 2003). Important elements of communication include the methods, the frequency and the information being exchanged. Communication is oft touted as a critical element for leaders and managers to possess, however, the media and frequency in which the communication is transferred can help or hinder knowledge exchange (Denise 2015). Co-ordination seeks to improve efficiencies between parties. Co-ordination ensures people know where they are going and their role in the whole scheme – the relationship between their effort and others' critical activities and roles. Important elements of coordination include the degree to which actors work together, the formality of their relationship, and the length of their relationship (Tatikonda and Stock 2003). Denise (2015) states that new ideas are often sparked not by consensus but by disagreement, dissent and even conflict. Co-operation risks being used as a tool to socialize a certain behavioural institution, rather than to enable a safe environment for new views and ideas to emerge. Denise (2015) notes that the opposite of co-operative is competitive, so actors can safely disagree while not competing. Important elements of co-operation include trust, congruence in vision and commitment level, with which there becomes safety in which to bring new ideas forward (Tatikonda and Stock 2003).

Rametsteiner and Weiss (2006) show that the benefits of interactions and relationships in place over an extended period are necessary in building the foundations for an effective innovation system in forestry, rather than coming together and building strong ties during the course of a single project. Enhanced trust and respect created and maintained through longer term interaction can lead to being more flexible in negotiating agreements and not impede further collaborative work. Jones *et al.* (2007) show how efforts made by the Australian fishing sector to increase the level of engagement between science and end users led to mutually rewarding relationships while also allowing sharing of data that reduced costs of gathering and processing research information. Moore *et al.* (2012) found the function of relationship building in forestry science projects to be critical, and that when science was being created with indigenous peoples in the New Zealand forestry sector, "*the additional time spent establishing trust and gaining the active co-operation of bodies and individuals with key roles as intermediaries for intervention design and implementation was found in most cases to be vital investment.*" (pg 646). Turner *et al.* (2014) in a study of effective interactions within New Zealand agricultural research and extension systems identified the need for interactions to occur between a variety of actors for enhancing knowledge exchange, and the value of farmers directly interacting with scientists in trials. The authors also found that a key challenge to the effectiveness of these interactions was the lack of linkage extension agency to translate and repackage the information for the receiver.

Conceptual framework

Formalized structures and emphasis on whole-systems are still required to support the building of relational networks, but the focus should be on building stronger relationships and knowledge-sharing institutions that support and build social capital (Kneller 2001), over the long-term and across a variety of projects rather than solely on the transfer of information. What is clear, however, is that an increased level of interaction between users and researchers is critical, and the nature of engagement may benefit from adopting less formalized structures. We posit that it is the informal structures that exist, and taking steps to grow the nature of the relationship itself rather than a focus on transferring knowledge within an innovation system that leads to an atmosphere for improved knowledge transfer to occur (Fig. 1). Stakeholder analysis and communication plans facilitate the structural and cognitive social capital built from formal relationships in which the context and knowhow of the various parties can be better shared. While this is often the outward manifestation of the relationship, relational social capital allows for tacit knowledge exchange, trust and deeper levels of engagement – elements that are not always outwardly apparent but underpin the ability for knowledge exchange to occur (Pelling *et al.* 2008). Such informal relationships lead to an organisational culture conducive to and designed/ primed for research knowledge to be implemented in the sector through enhanced co-ordination, communication and co-operation, increasing revenues and enhancing sectoral results. Linkage agents also work to take and repackage information from science, while also providing an important conduit to feedback knowledge and experience from industry.

We suggest that the relationship itself, especially when this is less formalized and when placed within a formal social interaction model, creates very rich environments in which knowledge exchange activities can occur.

Methods

Eighteen members of the wider forest network were interviewed and the qualitative results analysed to identify the presence of social capital and approaches used to facilitate knowledge exchange. The interview questions included mechanisms that researchers had taken to exchange knowledge with users, degree of interaction with the research programme and the means by which the members were receiving information.

One of the innovation clusters was selected as a case study to quantify the degree of interactions occurring within the network of 31 members. An online survey was developed through *SurveyMonkey* and distributed to members of the innovation cluster who had come together to investigate the

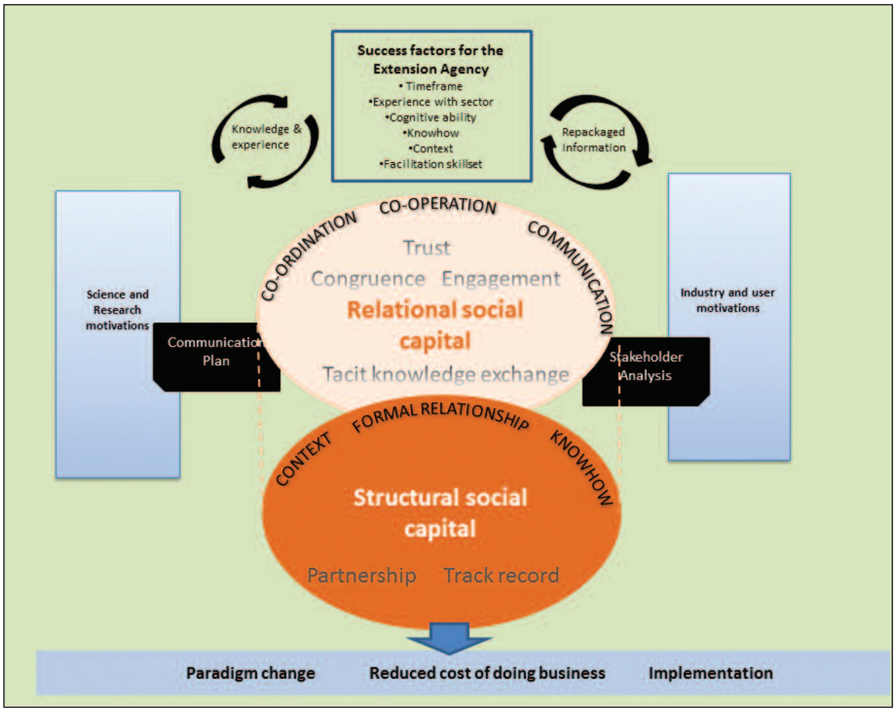

Fig. 1. Conceptual framework of structural and relational social capital activities in facilitating scientific knowledge exchange.

topic of wood quality and segregation methods. Social network analysis (SNA) provides a means to visually represent interactions between individuals within a network, whereby a matrix of relationships can be transformed into a network map or 'sociogram' (Williams and Hummelbrunner 2011). Two questions were used to determine both a) who within the cluster membership they were interacting with and how often; and b) whether the interactions concerned wood quality and segregation methods. The survey also identified persons outside the formal network that were party to wood quality and segregation knowledge due to informal networks. The degree of interaction was weighted in the following manner for the question "In the previous six months how often have you been in contact with the following people?": a) we talk fairly frequently (score = 6); b) several contacts have been made (score = 4); c) I know of the person but have not made contact (score = 2); and, d) I do not know them (score = 0). Scores were averaged for the member pairs, for example, where one person said they spoke frequently and the other that there had only been several interactions, a score of 5 would be given for the interaction. The survey also asked whether a conversation around wood quality or segregation methods had been held with the person. This resulted in a simple matrix of 0 and 1 where 1 indicated the topic was discussed between the pair. The survey responses (n=22) were placed into a matrix and entered into network analysis program UCINET to explore relationships, calculate the network centrality and construct a sociogram of network interactivity around the topic of wood quality and segregation methods.

Results

Early in the Future Forests Research (FFR) program, the tendency of researchers was to communicate the results of their work using the language of science and academics, and via formal written reports. Where the knowledge exchange was directly to end users, this was via a series of seminar presentations. A website was developed for FFR, on which all reports and presentations were made available to industry members for download on a shared portal. However, it became apparent when monitoring web traffic, that the reports and information were only being downloaded relatively few times – in other words, people in industry were not receiving the information or were seeking the information directly from scientists rather than by reading and disseminating research results outlined in reports. Obviously the information deficit model was not an effective means of transferring knowledge, and new approaches emerged in an effort to improve the transfer process. Interviews with respondents revealed that two modes of interaction proved very successful. The first was a series of interactive workshops which included both refreshing of basic knowledge and the integration of new research understanding into practical examples. The second approach was to recruit personnel into the program who were versed in both the science field, but also had some experience in industry, as knowledge brokers or agents. Scientists found that along with a larger uptake and interest in their work, a number of additional benefits occurred from these approaches. Firstly, an ability to learn about sectoral issues and priorities of the end-user; secondly, the opportunity to meet face to face, and 'put a face to the name' of particularly technical foresters within forest companies; and lastly, the ability to increase social capital.

Innovation clusters

Each cluster includes voluntary members from various interest groups with a background in the specific innovation cluster areas. Typically there is a core of about 10 people, but cluster events may attract up to 30 participants. The clusters operate on an open door philosophy and encourage others interested to join. A key success from interactive learning and knowledge exchange was seen in the field trips following six-monthly update meetings, where science, government agencies and industry were actively intermingling and communicating together while travelling between stops on the bus trips. Not only was the key science being exchanged, but stronger network ties were able to be developed through interactions that occurred on the day.

Network strength

The sociogram indicates a strong degree of interaction between participants within this innovation cluster, with all participants having spoken with at least one of the other members at least once or twice over a six-month period. In the case of the network conversations concerning wood quality and segregation methods, this showed a fairly centralized network (Fig. 2), more than twice as large as the estimated cluster network, with five stars (BB, H, K, P, J) holding the network interactions together. Surrounding the central hub are boundary spanners (Q, E, R, F) who are communicating the knowledge out into a wider network of people. More importantly, those who are only loosely connected to the network (by only communicating with one or two other members around the topic) show a very regular communication link with these members with high centrality scores of 4-5. The case study is showing evidence of increasing collaborative behaviours to bring about a prototype segregation tool. Results show that co-operative and co-ordinated behaviours are being encouraged through increasing the opportunities for informal engagement with involvement in field trips and sharing of data and experiences.

Discussion

When forming the new GCFF program, a concerted effort was made to enhance knowledge exchange through the formation of four innovation clusters to ensure interactive learning and allow for the establishment of new relational linkages to be created. The innovation clusters served a number of purposes. While the main purpose was to provide a forum to develop a deeper understanding of key issues, review science advancements and discuss the practical implementation of these, the clusters also facilitated the building of trust and enhanced co-operative developments by facilitating co-innovation and technology transfer and enabled interactive learning by actively engaging with stakeholders. A range of structured activities as formalized transfer mechanisms were established such as regular discussion meetings, seminars, and workshops, along with collaborative industry-led research activity. An interesting insight was that the workshops were supported by industry not only for the knowledge exchanges made in terms of science advances, but also for the

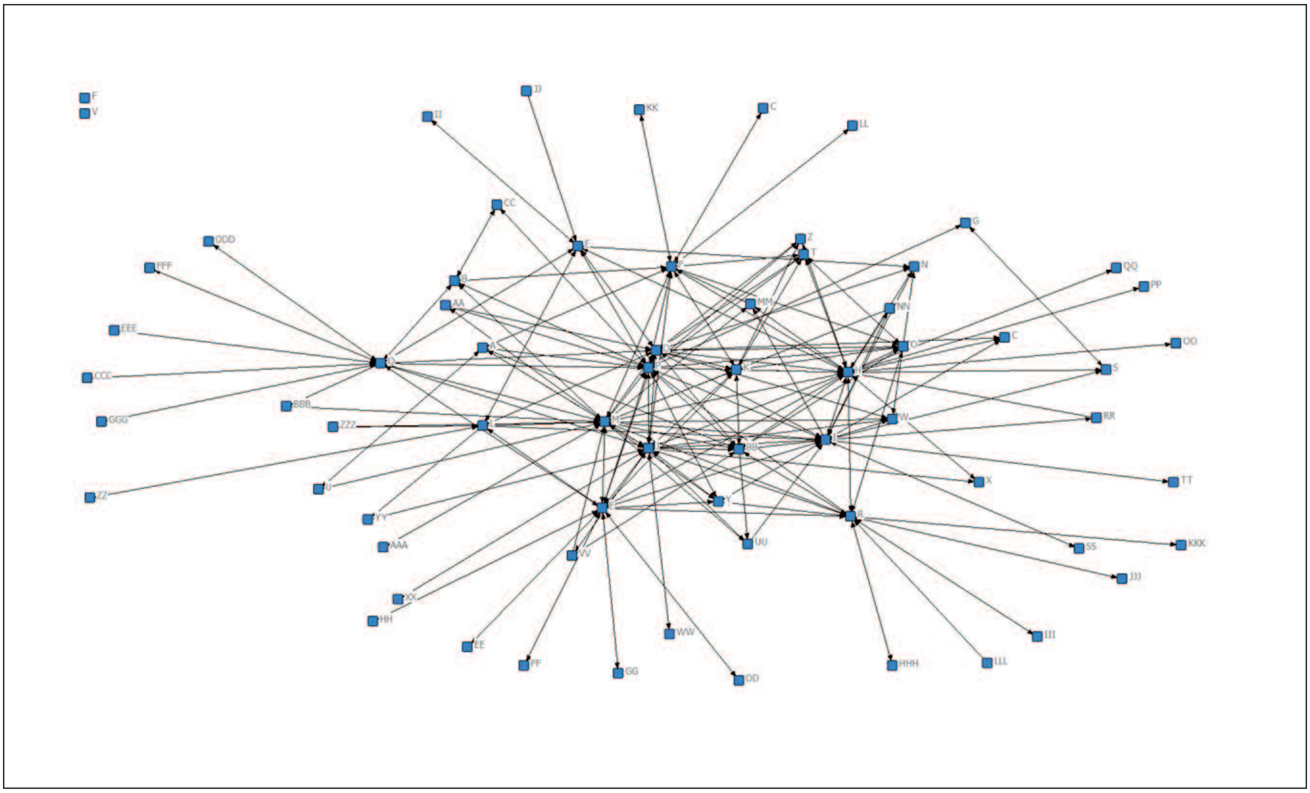

Fig.2. Sociogram showing degree of interaction between innovation cluster members and other participants concerning wood quality segregation tools. Each square represents a single actor in the network, with lines showing connections. The names of these actors have been removed for privacy reasons.

networking opportunities with other companies in the sector and the ability to meet informally and identify others 'of like mind' as potential collaborative partners. In some cases, the main reason participants noted for attending the workshop sessions was for the informal networking rather than the science knowledge dissemination, as the informal discussions were seen as a better method of enhancing business linkages. Those interviewed also described the continuation of business linkages formed from workshops and meetings through regular phone and email discussions as a critical means of strengthening the formal network, stating that it was through getting to know each other that trust was formed. The innovation cluster enables actors within the forestry sector with an interest in developing wood quality segregation tools to come together using active learning processes to address the systematic requirements of the research program.

Innovation clusters can develop organically from within existing industry connections but a cluster group requires a focus and goal to progress and accelerate knowledge exchange amongst the group. Learning occurs through engagement opportunities and innovation clusters can provide the formalized structure by which there is genuine engagement in a science program. Through interactive discussion and 'learning by doing' via demonstrations and field visits, participants can begin to build long-lasting social capital.

The importance of the linkage agent and the ability of scientists to be able to confer the knowledge in an appropriate manner to facilitate learning is a critical component to ensuring the success of an innovation cluster.

Sociograms can reveal the presence and identity of system bottlenecks (where information must pass to get from one part of a system to another); brokers, who span the boundary of the system with those not closely linked to other members; and central hub members or stars, who have the best access to information flows throughout the network and are strongly connected to other members. SNA was performed with one of the innovation cluster groups whose members were exploring the topic of improved processing through segregating on wood quality characteristics. The SNA mapped the current connections emanating from the cluster group among growers, processors and others in the forestry supply chain. Having strong networks is one thing; however, the purpose of the cluster and wider network is to facilitate conversations that lead to innovative timber segregation tools being co-developed. This obviously cannot occur if no one is discussing the segregation issue at hand through the interactions, or the conversations are either being kept within a 'tight few', or failing to include significant network players (especially key enablers or influencers). Correlations between the interactivity and the conversations concerning the cluster's purpose in terms of degree of centrality, indicate that some people, while well-connected, are having only few conversations about segregation. The stars are therefore critical to the leadership, communication and understanding across the network in relation to wood quality and segregation, and have the strongest levels of interaction with others in the network, indicating a high level of consistency in advanced science knowledge on this topic throughout the network. This indicates people are using their established existing networks to discuss the cluster group issues, rather than forming a new social network to address issues surfacing within the cluster meeting discussions. Knowledge should be exchanged more quickly and take less time to be incorporated into practice as conversations will occur naturally, although there may be a tendency to not look outside the obvious established network for information or dissemination of data. Those within the network who are stars in the central hub in particular will likely have developed the common language and context required to ensure effective exchange of knowledge—over time they will have learnt what types of knowledge different members require and may have developed specific translator skills to exchange information. It takes time to develop both sufficient credibility for effective engagement and cognitive understanding of the network structure, however these skills are usually only able to be honed in an environment of trust and openness, requiring a system that encourages greater levels of informal interaction.

There is scope to expand the conversations beyond the "obvious" interactions to fringe actors within the network and to use boundary spanners or brokers to facilitate conversations between the fringes and the stars. The network could be improved by encouraging these folks to discuss the issue to a greater level within their networks or alternatively, for others in the network (particularly the influencers and stars) to initiate conversations with these people, such that it becomes more pertinent topic of conversation when discussing other matters with colleagues and peers.

Conclusion

The conceptual framework was used to explain the presence of structural and relational capital within the New Zealand forest sector through a case study of an innovation cluster network. Our experience in providing a formal mechanism (innovation cluster) in which social capital can be built, has shown the importance of allowing informal engagement to flourish in order to achieve an environment in which innovation can occur and drive forest sector productivity. The exchange of knowledge, including tacit knowledge, depends on strengthened network ties in which the stars and boundary spanners within the system are critical. The speed of knowledge exchange can be enhanced due to relational dimensions of social capital, which increase trust, reciprocity of knowledge sharing, and a more direct linkage to influencers and enablers of sector change.

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Knowledge Exchange in the Canadian Wood Fibre Centre: National scope with regional delivery

by Steve D'Eon[1] and Katalijn MacAfee[1,*]

ABSTRACT

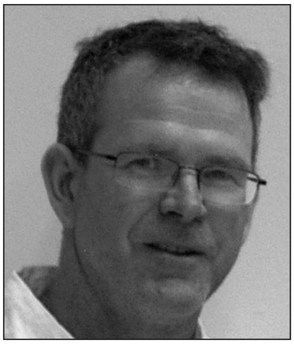
Since its inception in 2006, the Canadian Wood Fibre Centre (CWFC), a branch of Natural Resources Canada's Canadian Forest Service, has placed an emphasis on Knowledge Exchange (KE). KE at the CWFC has followed a progression from raising awareness, to generating interest, through to providing support for those deciding to adopt an innovation. Designing a program of national scope with regional delivery has led the CWFC to partner with different regional delivery organizations. Across Canada, Light Detection and Ranging (LiDAR) based Enhanced Forest Inventory has become a very successful innovation spearheaded by the CWFC in partnership with academia, the forest industry, and a growing consulting sector. The KE program for LiDAR based Enhanced Forest Inventory is used as an example to illustrate the CWFC's KE methods along with a description of regional delivery agencies and the success in getting this innovation adopted.

Keywords: knowledge exchange, LiDAR, enhanced forest inventory

RÉSUMÉ

Depuis sa création en 2006, le Centre canadien sur la fibre de bois (CCFB), une direction générale du Service canadien des forêts au sein de Ressources naturelles Canada, a mis l'accent sur les échanges de connaissances (EC). L'EC au CCFB a connu une progression importante passant de la sensibilisation à l'apparition d'un intérêt, grâce à l'aide fournie aux décideurs responsables d'adopter l'innovation. En créant un programme national tout en agissant au niveau local, le CCFB a établi des partenariats avec différents organismes livreurs régionaux. Dans l'ensemble du Canada, les inventaires forestiers améliorés à l'aide du Lidar (détection et télémétrie par ondes lumineuses) représentent une innovation très remarquée pilotée par le CCFB en partenariat avec les universités, l'industrie forestière et un secteur de la consultation de plus en plus important. Le programme des EC pour les inventaires forestiers améliorés à l'aide du Lidar sert à illustrer les méthodes d'EC du CCFB de même qu'à décrire les organismes responsables régionaux de livraison et le succès obtenu pour faire adopter cette innovation.

Mots clés : échange de connaissances, LiDAR, inventaire forestier amélioré



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Introduction

Canada's forests stretch east-west across the continent from the Atlantic to the Pacific oceans and from the southern border with the United States to the northern tree line in the Artic. The vast majority of Canada's 200 million ha of productive forest is owned by the provinces, whereas the federal government's role focuses on international trade, policy, and research. Within its research vein, Natural Resources Canada (NRCan) recognized the need for better integration between its forestry section, the Canadian Forest Service (CFS), and forest industry as a way to keep the Canadian forest sector innovative, sustainable, and competitive.

In response to this need, a new branch of the CFS was formed in 2006, the Canadian Wood Fibre Centre (CWFC). The CWFC was established without responsibility for infrastructure as a 'virtual institute' housed in eight different CFS research facilities (CWFC 2007). At the same time, the Canadian forest sector's industrial research organizations FERIC, Forintek, and Paprican merged to become FPInnovations. The CWFC and FPInnovations were also formally linked to create the largest forest research organization in Canada. This unofficial public-private partnership provided a link to innovative research solutions across the entire forest value chain, from genetically improved seedlings through to value-added consumer products. Merging the long-term ecological nature of CFS research with the more short-term applied research industry needs created a government branch that is nimble,

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flexible, efficient, and focused on delivering adoptable solutions for real-world problems faced by the sector. Close ties to the industry-focused FPInnovations has allowed CFS to bridge the gap between research and implementation.

Knowledge Exchange within the CWFC

When the Canadian Wood Fibre Centre was launched, CFS brought George Bruemmer on board as the new Executive Director. Mr. Bruemmer had led the Forestry Research Partnership (FRP) in Ontario very successfully and recognized that uptake and application of CWFC research would have to be facilitated by a culture and commitment to Knowledge Exchange (KE) throughout the organization (Bruemmer 2008, Smith *et al.* 2008).

Another aspect recognized early on was that success in KE would greatly increase by working closely with valued partners. One logical partner was FPInnovations and a joint CWFC and FPInnovations Knowledge Exchange Team was formed. Collaboration is on-going with regular team meetings, joint projects, and coordinated efforts. A more recent joint KE effort has been undertaken with the KE team from the CFS. With many research projects becoming cross-cutting between the CFS, the CWFC, and FPInnovations, these KE partnerships are valuable tools in efficiently delivering robust and adoptable innovations to the Canadian forest sector.

Other long-term KE partnerships continue with the Canadian Institute of Forestry (both their national office and Section offices), the Canadian Woodlands Forum (CWF) in Atlantic Canada, and Partenariat Innovation Forêt (PIF) in Quebec. To effectively implement its strategy, the CWFC also works with provincial professional associations, provincial forestry and/or natural resource departments, academia, and industrial partners. Regional partners bring local credibility, knowledge of important regional players and client base, use local terminology, respect local issues, and understand local ownership, management, and priorities. The CWFC's national and regional partners are essential to the success of KE.

One of the challenges, or perhaps benefits, at the CWFC is that research programs with both national research projects as well as more regionally focused projects all require management. Using a strategy of national program scope with regional delivery has served the CWFC's KE needs well in a forest sector that spans six time zones, two official languages, and countless ecological and business landscapes.

KE techniques used at the CWFC

The CWFC has always followed a well-documented progression towards adoption in its KE program. First, the breadth and depth of an innovation (or research component) are evaluated in order to identify the suitable market and potential end users. Breadth estimates how much land base or implementation base to which an innovation will apply. For example, an innovation that provides solutions for a tree species of national magnitude, such as white spruce, will have greater breadth than an innovation aimed at a tree species that grows in only one region of Canada such as black walnut. Depth refers to the degree the innovation will be used in terms of frequency, importance, and impact. For example, an innovation that alters a process and offers a one-time cost saving of a few dollars per process has less depth than an innovation that will alter a repeating process that is used hourly with a transformative impact. The combination of breadth and depth provides an estimate of the potential importance of the innovation to the forest sector. Secondly, the KE program evaluates whether an innovation is a 'push', a 'pull', or a 'drag'. A 'push' is an innovation that has not been requested and must be pushed upon end-users in order for them to recognize the benefits. A 'pull' is an innovation that fills a previously requested demand and has an existing market. A 'drag' is a regulatory requirement that the forest sector must meet and demand for the innovation is contingent upon the regulations remaining in place.

Rogers (2003) described five stages in the innovation-decision process: knowledge, persuasion, decision, implementation, and confirmation. Ahlander (1990) described four steps in the adoption process, calling the process a "stairway to change". The CWFC uses a five stage progression from discovery/research to support for adopters (Table 1). Feedback throughout the process improves the innovation. The CWFC progression is not implemented in a linear fashion as regions may be at different stages, and within a region there may be early adopters looking ahead, more cautious enterprises closely following the innovation's progress, and late adopters only monitoring the uptake before considering their situation. Flexibility is a key component in the CWFC KE program, but the general progression from discovery/research stage to adopting stage remains an integral part of CWFC KE planning.

KE products used by the CWFC

Implementing a successful KE program involves more than establishing the right partnerships and creating a culture of KE within an organization. The right KE tools have to be used at the right time to engage the right audiences. The CWFC carefully evaluates and uses limited resources, wisely matching the proper KE tool to the stage of adoption a target audience is at. As well, some innovations lend themselves better to certain KE products than others. Quite often a combination of tools delivered in sequence can be extremely valuable, for instance releasing a best practices guide and then following up six months later with an electronic lecture. Engaging CWFC researchers in delivering these high quality KE products is a continuous commitment and essential for their effectiveness and ultimately their success.

The CWFC uses many KE products including traditional hard copy publications, web-based learning products, in-person presentations, and more modern virtual field tours and complete tool kits (Table 2). CWFC research is often collaborative with multiple partners and CWFC KE events normally include a diversity of presenters from different organizations with multiple co-authors. Most CWFC KE efforts do not exclusively present CWFC research and tend to present non-CWFC research results within the same theme. In many cases the CWFC searches for the ideal partner to deliver a KE product and may provide direct financial support, logistical support, speakers or presenters, or participate in organizing the event. Partners are quite often better positioned to deliver a KE product and the CWFC is quite willing to support their complimentary efforts (MacAfee 2015).

Table 1. Overview of the CWFC KE progression

Adoption Stage	Tone	Audience	Goal	Products
Discovery/Research	Prove it	Other scientist, researchers, research managers	Ensure the science is valid	Scientific papers, Conferences, Symposiums, Posters
Raising Awareness Pass along knowledge	Tell me	Mass	Inform potential users of the innovation	Field Days, Demonstrations, General Presentations, Electronic lectures, Webinars, Brief web pages, Papers in general literature.
Generating Interest Persuade potential users	Show me	Group	Generate interest in adopting the innovation	Workshops, Demonstration Areas, Electronic lectures, Webinars, Technical notes, Professional papers, Articles in trade magazines.
Support for Decision Help them estimate their situation	Help me decide	Individual corporate	Support those contemplating adoption	Synthesis Reports, Compendium of results, Economic reports, Reports on those who have adopted, Case studies.
Support for Adopters Instruct how to do it	Instruct me	Individual one on one	Support those adopting	Field Guides, Manuals, Video instructions, 1-800 numbers, Best practices guides.

A CWFC KE success story: Enhanced Forest Inventory

Research in Enhanced Forest Inventory (EFI) has been a multi-partner effort to tackle one of Canada's long-standing forest management problems—providing an accurate and precise forest inventory on a forest manager's desktop (Wulder *et al.* 2008, Pitt and Pineau 2009, Woods *et al.* 2011). EFI uses airborne data collected using Light Detection and Ranging (LiDAR) which provides a computerized three-dimensional view of the ground (a digital terrain map) and morphological characteristics of trees including their crown shape and tree height. Detailed measurements of individual trees from ground plots and digital air photos complete the components used in EFI. The tree measurements are precisely lined up with the LiDAR-derived tree characteristics from which models are developed and applied across the land base.

EFI places on a forest manager's desktop a comprehensive inventory of statistically validated estimates of forest characteristics of interest for the entire land base under management (Woods *et al.* 2011). It provides forest managers with precise information on what is where and how to get there so that they can plan the best way to sustainably manage the forest.

One measure of success for an innovation is on how many hectares of forest land the innovation has been applied, and the breadth of the application. By early 2015, EFI had been created and used on over five million ha in Canada, while LiDAR had been collected for 25 to 30 million ha, with an additional 50 million ha in the planning stage (D'Eon 2015). It is estimated by the end of the 2016 season half of Canada's managed forest will either have, be producing, or be planning to collect LiDAR capable of creating an Enhanced Forest Inventory.

Users of the technology found they used EFI for twice the number of applications they expected and this formed a basis for their business case to purchase the technology (D'Eon *et al.* 2015). James D. Irving described the technology to the House of Commons Standing Committee on Natural Resources with this statement: "*It's a Game-Changer*" (Parliament of Canada 2015). An early report by the U.S. Forest Service (USFS) provided a favourable comparison of the costs-benefits of a LiDAR-based inventory versus a traditional inventory for annual sampling in a 500 000 ha even-aged managed forest, reporting time savings of 28 % and dollar savings of 45 % (Renslow *et al.* 2000). A 2011 study by the USFS in Oregon on an operational implementation of LiDAR-based EFI concluded it was cost competitive compared to traditional methods for areas of 20 000 ha and greater (Hummel *et al.* 2011). The State of Maine has reported a benefit to cost ratio of 4:1 with a payback of 2.3 years for all uses within a State sponsored LiDAR acquisition (Carswell

Table 2. Various CWFC led KE products and their benefits

KE product	Effort/ Cost[1]	Audience	Distribution[2]	Benefits
Special edition of a practitioner journal such as *The Forestry Chronicle*	Very High $$$	Practitioners, managers, scientists	Subscribers plus libraries.	Reaches a broad targeted audience with detailed content. Journals have a very long shelf life.
Article in a trade magazine such as *Logging and Sawmilling*	Low $	Industry, managers, practitioners.	Subscribers plus website downloads.	Reaches a targeted audience with summary information. Medium shelf life.
CFS Technical Note such as *Fibre Facts*	Medium $	Industry, practitioners.	Open, unlimited downloads from CFS Bookstore.	Good vehicle for raising awareness or providing more detailed content. Medium shelf life.
CFS Information Reports	High $	Practitioners, managers, scientists	Open, unlimited downloads from CFS Bookstore.	Good vehicle for providing detailed content such as case studies. Good shelf life.
Electronic Lecture	Medium $	Very broad	Open. Typically 400 to 700 participants	Good vehicle for generating interest. Very short shelf life.
Short one or two-day workshops	Low to Medium $ to $$	Local to regional; targeted to general.	20 to 200, Limited	Can provide detail and interactions with the audience. Can be instructive.
Field days/tours	Low to High $ to $$	Local, targeted.	10 to 100, Limited	Very good learning experience for the audience.
Virtual tours	High $$	Local to regional, broad.	Open, unlimited.	Most of the experience of a field day without the audience travelling.
Best Practices Guides	High $	Targeted to those deciding to adopt.	Depends upon the publisher.	Instructional. Important for those at the decision to adopt stage.
Took kits	Very High $$$	Local to regional. Targeted to those deciding to adopt.	Open, unlimited.	Instructional. Important for those at the decision to adopt stage.

[1]Effort refers to the resources required to create the product. Cost refers to typical direct costs to the CWFC excluding translation.
$ = $0 to $1000, $$ = $1000 to $10 000, $$$ = > $10 000.
[2]Printing and distribution of hard copies for CFS publications are evaluated on a case by case basis and not included in this table.

2014). Forest resource management was ranked as the third greatest benefit. An Australian study in a 250 000 ha forest showed positive cash flow after two years and a five-year total NPV of AU $1.4 million (Brown and Sutton 2012).

Despite these documented benefits, EFI did not sell itself. LiDAR and EFI were viewed as an expensive alternative to traditional methods (Lacroix and Charette 2013). Forest industry perceived inventory as provincial responsibility. From a KE perspective, EFI does not have features that make it easily adopted: EFI is difficult to test on a trial basis, as collecting airborne LiDAR is price-prohibitive per ha for smaller areas and rapidly comes down in price as the area surveyed increases. Furthermore, the technology does not layer onto existing forest inventories but instead replaces them, and the skill required to build and operate an EFI are usually not found in-house in a forest company.

To overcome these barriers and others, the CWFC adopted a partnered plan in 2011 to raise awareness, generate interest, and support the decision to adopt LiDAR and EFI (Table 3).With a culture of KE embedded in the CWFC, the KE program benefited from researchers being willing and active participants in presenting EFI to audiences from coast to coast. The research program also found industrial partners in four separate regions to undertake management-unit scale EFIs as 'flagship' sites. The flagship sites served as proving grounds for implementing the technology, refining the research, and generating results others could perceive as relevant to their situation.

During the early phases, KE efforts focused on presentations at workshops, forums, tradeshows, seminars, and conferences, making 114 presentations compared to producing 27 reports (Bruemmer 2012). The KE program set its goal that every working forester in the country would have heard of the program in two years. To test this assumption, in 2012 the CWFC along with FPInnovations undertook a limited informal survey of 76 companies and provincial agencies and found that all respondents had heard of the technology (D'Eon and Kurowski 2012). More than half of the respon-

Table 3. Overview of the 2011 adoption plan for the enhanced forest inventory program

Adoption Stage and time frame	Research, trial pre 2011	Roll out 2012–2013	Peak adoption effort 2012–2014	Update 2014
Discovery	<-------------------------------------	Research Team	------------------------------------->	
Raise awareness	Research team, CWFC KE team	Research team, CIF/CWFC/FPI KE team	–	–
Generate interest	–	Research team, CIF/CWFC/FPI KE team	Research team, KE team	–
Support the decision to adopt	–	–	Research team, CWFC/FPI KE team, technical specialists	KE team, technical specialists
Technical support for adopters	–	–	FPInnovations, Consultants	FPInnovations, Consultants

dents were interested but not yet moving towards adopting the technology, and only 11 % were in the process of evaluating whether to adopt the technology or not. In response, the KE program reduced emphasis on raising awareness and increased emphasis on case studies and workshops presenting peer-to-peer regionally applicable results. Between 2012 and 2014 dedicated workshops were hosted across the country by various partners, including PIF in Quebec, CWF in Atlantic Canada, and the CIF/IFC in every province except Nova Scotia and PEI.

As interest grew, the KE program switched to overcoming specific issues such as the perception that EFI was costly. Demonstration sites and impact notes described the technology and the benefits flowing from the flagship partners (Wang *et al.* 2012). On occasion results were analyzed for a specific target audience to present real costs directly applicable to the audience (D'Eon 2013). To assist broadly in the decision to adopt, the KE program funded a suite of regional workshops hosted by the CIF/IFC with the University of British Columbia and FPInnovations that provided hands-on training to ease the concern that the technology was difficult to use. The CFS published a best practices guide to clearly document the methods used (White *et al.* 2013). This guide was supplemented with an electronic lecture hosted by the CIF/IFC that was the most attended e-lecture in the Institute's history of electronic lectures with 675 participants (Meade 2014).

In 2014, the CWFC in collaboration with the CIF/IFC conducted a broader email survey from a contact list of over 1 000 and found a very high satisfaction rate amongst adopters (FPInnovations 2015), yet the perception of high costs remained with those not using the technology (D'Eon *et al.* 2015). Again adjustments were made to the KE program in response to the user community needs with an emphasis on actual costs and real world applications (Kurowski and D'Eon 2015, Pitt 2016, Vekeman 2016). As adoption became heavily embedded in some regions, the KE program relied upon users telling their stories, such as Tembec in Ontario (Bernier 2015), J.D. Irving Ltd. in New Brunswick (Dick 2013, Pitt 2015), or Corner Brook Pulp and Paper in Newfoundland (Moulton 2013). EFI suppliers started advertising their services and providing training (Côté-DeMerchant 2016).

Conclusions

From its inception, the CWFC has strongly supported a meaningful and comprehensive KE program. The process guides an innovation or research outcome from the discovery stage, through creating awareness and raising interest, to providing support for the decision to adopt. The CWFC uses various KE products tailored towards specific audiences and with targeted benefits. The CWFC also recognizes the strength of using partners and collaborators. The CWFC KE Program is seen as the cream of the crop within the CFS when it comes to KE, and this is partly due to the relationship with its partners. Since 2006 the CWFC KE program for Enhanced Forest Inventory has evolved and used appropriate partners to provide KE product users needed to progress towards their decision to adopt. Adoption, judged by hectares where the innovation is applied or in the process of being applied, confirms the program's success.

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An approach for the use of agricultural by-products through a biorefinery in Bangladesh

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ABSTRACT

The global need for developing renewable, sustainable, biomaterials, biochemicals and biofuels continues to grow along with increasing worldwide desire to reduce fossil-fuel emissions. An appealing source for bio-based products is lignocellulosic resources, which are abundant, low cost, and are often a by-product of food production (mainly rice). This paper gives an approach for bio-based product development in Bangladesh by analyzing i) a comprehensive inventory of agricultural and lignocellulosic wastes, ii) the characteristics of these wastes, and iii) suitable methods for producing bio-based products. It is proposed that a cooperative society be set up amongst the rice producing farmers and communities. Entrepreneurs would collaborate with this cooperative society to implement the approach, and biorefinery plants could be established in different parts of the country based on the amount of available agricultural wastes in specific areas. As forest area is very limited and population density is very high in Bangladesh, wood resources cannot be utilized in biofuel, biochemicals and biomaterials production in the country, making agricultural by-products the only real option available.

Keywords: bio-based products, pulp and paper, agricultural wastes, community engagement

RÉSUMÉ

La demande mondiale pour la mise au point de biomatériaux, de produits biochimiques et de biocarburants à la fois renouvelables et durables connaît une croissance soutenue, tout comme la demande mondiale pour réduire les émissions de combustibles fossiles. Les abondantes ressources lignocellulosiques offrent une source intéressante de bioproduits à la fois peu dispendieuses et qui constituent un sous-produit de la production alimentaire (principalement celle du riz). Cet article propose une approche pour l'élaboration d'un bioproduit réalisée au Bangladesh en analysant i) l'inventaire global des résidus agricoles et lignocellulosiques, ii) les caractéristiques de ces résidus et iii) les méthodes adaptées à la production de bioproduits. Nous proposons la mise en place d'une coopérative réunissant les producteurs de riz et les collectivités. Des entrepreneurs pourraient collaborer avec cette coopérative pour la mise en œuvre de cette approche menant à la construction de bioraffineries dans différentes régions du pays en fonction de la quantité de résidus agricoles disponibles sur place. Comme il y a peu de terres boisées au Bangladesh et que la densité de population y est très forte, il n'est pas possible d'utiliser les ressources ligneuses pour la production de biocarburants, de produits biochimiques et de biomatériaux, si bien que les sous-produits agricoles demeurent la seule option possible.

Mots clés : bioproduits, pâte et papier, résidus agricoles, engagement communautaire

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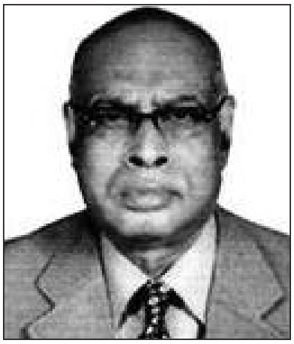

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Introduction

Bangladesh is a densely populated country with a population of 161 million in 2015 (FAOSAT 2016) and a total area of 14.76 million ha (Kibria *et al.*2000). Forest lands comprise 2.53 million ha, with 1.53 million managed by the Bangladesh Forest Department (BFD). A vast area of 0.73 million ha, termed Unclassed State Forest (USF) is almost barren and is under the control the district administration of the hill districts (Akhtaruzzaman 2010). While land managed by the BFD is legally defined as forest land, a significant portion does not have any trees; tree cover amounts to 48.8% and the remaining 51.2% is denuded and degraded (Kibria *et al.*2000).

According to the National Forest Assessment 2005–2007, cultivated land is 56% and forest land under the management of BFD is close to 10% of the total area of Bangladesh (Altrell 2007). As shown in Table 1, 84% of the total forest area is classified as natural forest and 16% as plantations. The two largest forest types are hill forest and mangrove forest, and together they cover more than 66% of the total forest area. Bamboo forest is about 13% and long-rotation plantations almost 10% of the total forest area. Short rotation plantations are about 4%. Only 3% of these short rotation plantations have 3%–70% tree cover and 48% has 10%–30% tree cover (Altrell 2007). There are several reasons for low tree cover:

Table 1. Forest types and area in Bangladesh (Altrell 2007)

	Forest type	Area (1000 ha)
Natural forest	Hill Forest	551
	Sal Forest	34
	Mangrove forest	436
	Bamboo/broad-leaved forest	184
Plantation forests	Long rotation forest plantations	131
	Short and medium rotation forest plantations	54
	Mangrove plantations	45
	Rubber plantations	8
Other wooded land	Shrubs	266
	Swamps with shrubs	23

- Continuous pressure to convert forest lands to agricultural, as well as urbanization, industrialization, and road construction;
- Encroachment of forest land for illegal settlement is an alarming danger to the forestry sector;
- Over-exploitation of timber and fuelwood to meet the demands for a growing population;
- Shrimp cultivation along coastal areas has reduced forest cover;
- Land litigations that avert forestry activity;
- Funding and human resources are inadequate;
- Limited public understanding of forests and sustainable forestry practices; and,
- Corruption within forestry department staff.

The British government first introduced forest policies on the Indian subcontinent in 1894, which were inherited by Bangladesh. With these policies, the conversion of forest lands to agriculture was prioritized and the preservation and conversion of resources had little consideration. After independence from British colonial rule, the Pakistan government formulated forest policies in 1955 where formal forest management planning processes, followed by inventories of different forest zones, were introduced as mandatory. The first national forest policy of independent Bangladesh was introduced in 1979. The policy was not implemented fully due to inconsistencies and contradictions. Positive impacts of this policy included a large-scale coastal mangrove plantation during the 1980s which was not managed properly due to inappropriate land tenure agreements. This new policy also extended forestry lands to the northern part of Bangladesh.

The latest forest policy was formulated in 1994 and emphasized the participation of local communities to create tree plantations outside designated forest areas. Women's participation in homestead and farm forestry was also encouraged with this policy. A target was set to make afforestation 20% of the country's land under the programs of the government and private sector by the year 2015 through active participation of the people to achieve self-reliance in forest products and maintenance of an ecological balance. Muhammed *et al.* (2005, 2008) reported that forest cover increased by only 0.14% per year, far below the targeted 0.5% in the 1994 forest policy. They considered that the policy either was not followed properly or the estimated target was unrealistic.

The 1994 policy included some initiatives for forest products. Emphasis was on the use of modern and appropriate technology at all stages of extraction and processing. The policy provided information on how modernization might ensure maximum utilization of raw materials, encouragement to grow fruit trees along with the production of timber, fuelwood, and non-wood forest products. State-owned forest industries were supposed to follow this policy to create a more competitive market and small-scale. Cottage industries were also encouraged in the rural areas but so far, no forest-product operations have been implemented. This may be due to lack of recognizing the importance of the knowledge of technological advancement, or perhaps a lack of organization of partners that can support the policy.

The section on the biorefinery concept in this paper shows that various products can be obtained from fibrous raw materials from non-forest sources – i.e., agricultural wastes during chemical conversion. This creates an opportunity for economic growth by engaging farmers and their communities in the development of a biorefinery approach that efficiently allows the use of these wastes. It also potentially lessens the use of valuable forest resources from already depleted and marginal forest lands. Existing forest policies should be updated to reflect these opportunities.

Availability of non-wood fibre in Bangladesh

Agriculture in the country has grown at 3.2% annually in the period 1991–2005 .The dominant reason for this growth has been the crop sub-sector growing at 2.3% per annum. Total food grains production, according to the Bangladesh Bureau of Statistics (BBS) in 1991–92 was 19.3 million metric tons, which has gradually increased to 29.8 million tons in 2007–08, 6.1% higher than the previous year's production. Rice, pulses, wheat, potato, tea, maize, sugar cane, cotton,

Table 2. Availability of important crops and waste generated in 2014 (FAOSTAT 2016)

Crops	Production (MT)	Waste generated (MT)
Rice	52 231 000	78 346 500
Wheat	1 302 300	1 953 450
Maize	1 525 000	1 525 000
Sugar cane	4 121 350	1 524 900
Jute	1 391 000	1 391 000

and oilseeds are the major crops. Table 2 shows the availability of some important agricultural wastes but data are scarce. Data reported here are based on the production of crops (FAOSTAT 2016). Agricultural wastes were calculated by the ratio of crops and wastes from one acre of land. Straw is produced at the rate of 1.4–1.5 MT/ ton of grain. The main crop residue is rice straw which is mainly consumed as fodder, and is the most abundant agricultural waste (78.3 million MT), followed by wheat straw (2.0 million MT). Bagasse production after extracting juice from sugar cane is 37% or about 1.5 million MT. Maize stalks produce about 1.5 million MT. Other minor crop residues are potato and cotton stalks, rapeseed and mustard stalk. These may be used as supplementary lignocellulosic fibres.

Jute is one of the most important natural fibres in Bangladesh and has a long historical role in the socio-economic development of the country. Once it was known as the "Golden fibre of Bangladesh". The export of jute (burlap, hessian) and related products accounts for a significant portion of the total export. In addition, it provides considerable employment opportunities to the country's work force. The chemical and morphological characteristics of jute show excellent quality compared to other lignocellulosic raw materials (Jahan *et al.* 2007a). It has high cellulose and low lignin content, advantageous for processing. In Bangladesh, jute fibre production in 2013 was 1.4 million MT. There are many jute textile mills producing fibre products such as bags, fabrics, and rope. In such operations, the bottom part of the plant is not utilized due to inferior properties. Thus, this portion of jute removed in these mills is commonly known as jute cuttings and account for 15% of the fibres. There are strong economic and social incentives to make value-added products from jute cuttings and these wastes and industrial crops can be important raw materials for pulp and paper industries.

Present status of the pulp and paper industry

The pulp and paper industry is one of the major producers of forest products. Bangladesh Chemical Industries Corporation (BCIC) was a key player for pulp and paper production. There were four pulp and paper mills under the umbrella of BCIC, *viz.* Karnaphuli Paper Mill (KPM), Khulna Newsprint Mill (KNM), North Bengal Paper Mill (NBPM) and Sylhet Pulp & Paper Mill (SPPM). Unfortunately, at present only KPM is in operation with yearly capacity of 30 000 MT. This mill was commissioned in 1953. One of the main reasons that the other mills closed was due to a shortage of fibre supply. KNM, a newsprint mill, started in 1959 with an annual capacity of 50 000 MT and used gewa (*Excoecaria agallocha* L.) wood from the Sundarbans which has been declared by the UN as a world heritage site. Due to the restrictions on gewa, BFD stopped the supply and consequently the mill was forced to shut down. NBPM, a bagasse-based pulp mill, was commissioned in 1973 with an annual capacity of 15 000 MT for writing and printing paper. However sugar production decreased remarkably and bagasse availability also decreased and led to the closure of the mill. SPPM, the only pulp mill based on reeds, began production in 1975 with an annual production of 20 000 MT. With increasing limited availability of reeds, SPPM started using hardwoods which subsequently depleted and the mill was closed down. In addition, BCIC has a joint ownership on the Magura Paper Mill, which produces packaging paper at around 15000 MT per year (Quader 2011).

BCIC's pulp and paper capacity accounted for around 90% of Bangladesh's output 25 years ago. Today BCIC is producing < 5% of the total paper products in the country (Quader 2011) as private investment now dominates in the Bangladesh pulp and paper industry.

Per capita paper and board consumption is about 3.5 ~ 4.0 kg/year, which is much lower than that for a typical developed country (about 300 kg/year/person), and substantially lower than the Asia average of around 30 kg/year/person. Therefore, it is desirable that there be a rapid increase of pulp and paper production in the country.

All of the new mills are using waste paper and imported market pulps. In 2014, Bangladesh imported about 162 878 MT market pulp at US$ 162.8 million, and also imported 137 707 MT writing and printing paper and 352 075 MT of paper board (FAOSTAT 2016). These figures create a strong case for Bangladesh needing more pulp and paper mills to reduce its dependency on imported pulp, paper and paper products. Since forest resources are already limited, alternative resources require investigation including agricultural wastes and industrial crops such as jute, kenaf, and dhaincha. These may therefore supplement traditional raw materials. The production of local pulp to reduce the dependency on imports is very important in face of the price hikes of imported pulp.

The biorefinery concept

A biorefinery is analogous to a petroleum refinery where all fractions of biomass are separated to produce fuels, value-added chemicals and biomaterials (Amidon *et al.* 2008). The success of the biorefinery concept depends on the efficient utilization of all incoming bio-resources. The shift from petroleum hydrocarbons to highly oxygen-functionalized, bio-based feedstocks will create remarkable opportunities for the chemical processing industry. Biomass carbohydrates can provide a viable route to products such as alcohols, carboxylic acids, and esters. In the IFBR (integrated forest biorefinery) concept, higher value-added products such as ethanol, polymers, chemicals, carbon fibres, and liquid fuels can be produced in addition to pulp (Cabrera *et al.* 2016, Sun *et al.* 2016, Zhang *et al.* 2016). This concept has attracted researchers and manufacturers to devote efforts on both wood and non-wood materials (Zhu *at al.* 2011, Joubert *et al.* 2016, Kim *et al.* 2016). Wood resources in Bangladesh are very limited therefore we have to concentrate on non-wood based IFBR.

In the IFBR concept, pre-treatment is an important stage where cellulose remains unaffected with limited extraction of hemicelluloses. The pre-treatment stage as a part of delignification has been claimed to enhance the digestibility of the remaining material (Al-Dajani 2008, Yoon *et al.* 2008, Jahan *et al.* 2015a,). This is strongly supported by the investigation on the pre-hydrolysis of non-wood materials (Jahan *et al.* 2009, 2012a, 2012b). Pre-hydrolysis reduced the chemical charge and cooking time to reach same delignification degree (Yoon *et al.* 2008, Jahan *et al.* 2015). However, an acidic pre-treatment may have a more negative effect on pulp strength properties compared to an alkaline pre-treatment, which may simultaneously enhance the impregnation of cooking alkali in the next stage (Jahan *et al.* 2015b). Alkaline pre-extraction of rice straw produced pulp of higher yield and strength properties compared to mild acidic extraction (Jahan *et al.* 2012a). Similarly, dhaincha (*Sesbania bispinosa* (Jacq. W. Wight) also showed better pulp yield and papermaking properties when pre-extraction was carried out with weak alkali charge (Jahan *et al.* 2012b).

A higher percentage of silica, hemicelluloses, and fines limit non-wood use as pulping raw materials. Thus, the difficulties in technology, economy and environment adversely affect non-wood utilization in pulp production. Pre-extraction prior to pulping agricultural wastes improved drainage resistance and increased paper machine function, and at the same time extracted hemicelluloses, lignin and acetic acid (Jahan *et al.* 2009, 2012b) which may be final products or raw materials for another downstream process. The pre-extraction prior to pulping removed pith from bagasse, corn stalks, and *S. spontaneum* (Jahan *et al.* 2009, Jahan and Rahman 2012b). Pith is non fibrous but chemically similar to fibre which contains cellulose, hemicelluloses and lignin (Jahan *et al.* 2009). Auto hydrolysis prior to pulping extracted 2% (on raw material) acetic acid and 8% sugar from corn stalks (Jahan and Rahman 2012b). Hot water extraction of rice straw extracted 15% hemicelluloses, while alkaline extraction extracted 10% hemicelluloses (Jahan *et al.* 2012a). Alkaline extracted rice straw produced higher pulp yield and properties. Similarly, alkaline pre-extracted dhaincha produced better pulp yield and properties (Jahan *et al.* 2012b). The pre-extracted non-wood material produced pulp with improved drainage resistance and maintained yield and strength properties. Pre-hydrolysis lignin is lower in molecular weight and higher in phenolic groups (Jahan *et al.* 2012c), which increases the possibility of use in phenol-formaldehyde resin preparation and other phenolic resins (Wang *et. al.* 2012). It may be concluded that pith and high fines containing non-wood material are suitable for pulping in integrated biorefinery process.

Another approach is organic acid fractionation. Acetic acid and formic acid processes are effective alternative methods to delignify lignocellulosic materials to produce pulp for paper and cellulose (Pan and Sano 1999, Xu *et al.* 2006, Jahan *et al.* 2007a, 2007b,). The three dominant components in lignocellulosic biomass— cellulose, hemicellulose and lignin—may be effectively separated by acetic acid or formic acid in a biorefinery (Fig. 1). The pulping operation can be carried out at atmospheric pressure and the acid used easily recovered by distillation and reused in the process. Acetic acid and formic acid treatments followed by peroxy acid delignification produced pulp with higher yields and acceptable strength properties from different non-wood materials (Jahan *et al.* 2007a, 2007b). Organic acid lignin is an optimal feedstock for many value-added products due to its lower molecular weight and higher reactivity (Kubo *et al.* 1995, Wang *et al.* 2012). The sugars from hemicelluloses are easily converted to chemicals and fuels. Another advantage of organic acid pulping is the retention of silica on the pulp fibre that facilitates efficient recovery of cooking chemicals (Sundquist 1996, Seisto and Poppius 1997). It has been reported that organic acid delignification of rice straw followed by alkaline extraction and conventional $D_0E_pD_1$ bleaching produced dissolved pulp with 94% purity (Jahan *et al.* 2015a). In addition to dissolving pulp, silica, lignin and hemicelluloses were also separated.

The Pulp and Paper Research Division of BCSIR Laboratories has carried out extensive research on non-wood fractionation by organic acid, where cellulose, hemicelluloses, lignin and silica are separated. The fractionated biomass can be used in producing biofuels, biochemicals and biomaterials. Acetic acid and formic acid treatments followed by peroxy acid delignification produced pulp with higher yield and acceptable strength properties from different non-wood materials (Jahan *et al.* 2007a, 2007b). The peroxy acid delignified pulp showed a good bleachability on alkaline peroxide bleaching. The dissolved lignin and C-5 sugars were easily separated. Organic acid lignins have a high phenolic content with lower molecular weight that permits high reactivity with different monomers producing new polymers and new formaldehyde-free adhesive formulations (Jahan *et al.* 2007c). Carbon fibres can be produced from the lignin by thermal spinning followed by carbonization (Kadla *et al.*, 2002). A fusible lignin with excellent spinnability properties to form a fine filament was produced with a thermal pre-treatment under vacuum.

The problem associated with fines and silica of non-wood pulping may be solved by the organic acid process. So it can be said that pre-extraction prior to pulping or organic acid

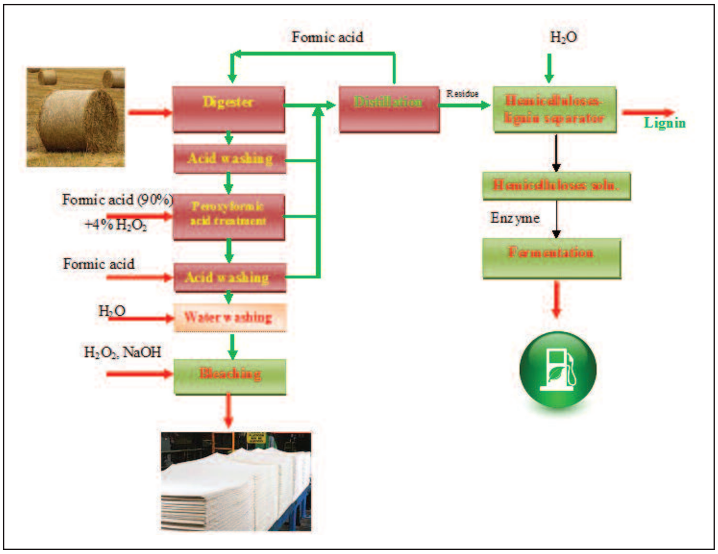

Fig. 1. Organic acid pulping of agricultural wastes in biorefinery concept

fractionation are the best choice for non-wood pulping which integrate biorefinery. Bangladesh Forest Policy should include non-wood-based biorefinery for pulp production instead of wood.

Partnerships for agricultural wastes based biorefinery

Bio-based product development initiatives in Bangladesh should be focused on agricultural wastes. To get a sustainable supply of raw materials, farmers need to be involved in the production process. Therefore, it is required that a cooperative society among the farmers is established. This will help to smoothly run a small scale biorefinery as shown in Fig. 2.

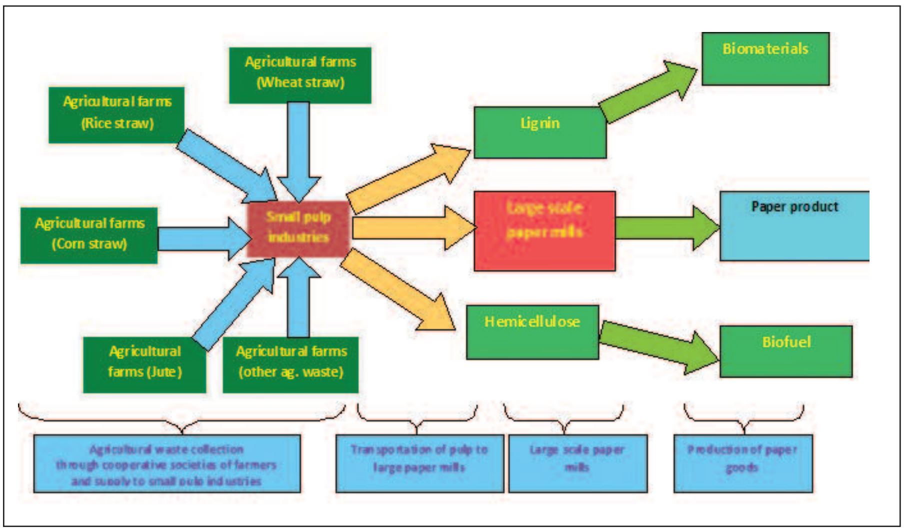

Fig. 2. Cooperative society of agricultural wastes based biorefinery

Similar cooperative societies are functioning among sugar cane farmers in India, USA and Mauritius. Entrepreneurs, preferably non-government organizations, can collaborate with the cooperative society to implement the biorefinery. Ultimately, the farmers will provide raw materials to the mill and get value for the raw material. Government policy is to increase income from agrarian products and by-products through value addition with minimum or no environmental damage. This concept will directly facilitate the farming community's economy and consequently improve livelihoods. All steps in this approach are environmentally friendly, all products and by-products are used in bio-based high-value added products, and ultimately it is expected to bring a good economic return, making important contributions to the development of local economies. In addition to pulp, bio-based products from dissolved lignin and hemicelluloses will replace petroleum products to a certain extent, which may reduce the greenhouse effect.

Conclusion

Research is ongoing all over the world to reduce greenhouse gas emissions through the viable production of biofuels, biochemicals and biomaterials from renewable resources that replace fossil fuel (Van Heiningen 2006, Wising and Stuart 2006, Xiang *et al.* 2015). Forest areas are limited and population density is high in Bangladesh, consequently wood resources cannot be utilized. On the other hand, Bangladesh is an agricultural country and generates substantial amounts of agricultural wastes. These may be alternative resources to produce bio-based products. To use agricultural resources, new technologies and strategies need to be adopted which are already developed in Bangladesh. Agricultural wastes-based IFBR can be a viable option for producing biofuel, biochemicals and biomaterials in addition to pulp. This concept can also solve problems relating to agricultural wastes pulping. Organic acid fractionation of agricultural wastes is another viable choice. To get sustainable supplies of raw materials and implement IFBR farmers need to be involved in the production process through the set up cooperatives. These strategies and technologies should be incorporated in recent forest policies. This paper briefly examined the present status in forestry in Bangladesh. The traditional forest resources in the country cannot meet the demand of the pulp and paper industries, resulting in the closing down of three main mills. However, there are many agricultural residues that can supplement forest raw materials for pulp and paper making. To this end, considerable studies have been done. There is a strong possibility of obtaining a multiple of products including pulp from the agricultural residues using the concept of a biorefinery. Still more research is warranted based on agricultural residues.

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Into the woods: Partnering with the Department of Corrections to deliver forestry extension programming

by Jason S. Gordon[1,*], Scott Cagle[2], John D. Kushla[3] and Brand Huffman[4]

ABSTRACT

This paper describes a pilot series of extension programs delivered to inmates within the Mississippi Department of Corrections system. The project was a collaboration between the Chickasaw County Regional Correctional Facility, state Extension forestry specialists, and county Extension staff. A large body of research describes benefits of inmate education, including lower recidivism and reducing tension that could otherwise lead to behavioral problems. Over four months, Mississippi State University Extension personnel worked with prison officials to educate inmates about forestry, logging, and arboriculture. This paper describes the collaborative process driving the project as well as program design, curriculum, materials, and delivery. Besides technical information, instructors discussed opportunities and challenges inmates may encounter if they were to pursue employment in forestry or tree care following their sentences. Instructors worked closely with prison staff to appropriately address teaching in a unique environment and the educational needs of the students. We present the student evaluation process, which was limited by prison rules. Finally, we present results from an evaluation of partners and instructors that elaborate on pitfalls, challenges, and opportunities. The Department of Corrections was highly satisfied with the program and has requested expansion to facilities across the state.

Keywords: forestry extension, prison training, U.S. South, arboriculture, vocational skills, special needs

RÉSUMÉ

Cet article décrit une série de programmes pilotes de formation donnée à des détenus du Département des services correctionnels du Mississipi. Le projet est né de la collaboration entre l'établissement pénitentiaire régional du comté de Chickasaw, les spécialistes en formation forestière de l'État et le personnel responsable du transfert technologique pour le comté. De nombreuses recherches démontrent les avantages de former les détenus, notamment un niveau plus faible de récidive et une réduction de la tension qui pourrait autrement engendrer des problèmes de comportement. Pendant quatre mois, le personnel du service de consultation de l'Université de l'État du Mississipi a travaillé avec le personnel de la prison pour enseigner aux détenus la foresterie, l'exploitation forestière et l'arboriculture. Cet article décrit le processus collaboratif, la base de ce projet, ainsi que la structure du programme, son contenu, le matériel pédagogique et les méthodes de prestation. En plus du contenu technique, les instructeurs ont analysé les possibilités et les défis que les détenus pourraient rencontrer s'ils voulaient poursuivre une carrière en foresterie ou en arboriculture une fois libérés. Les instructeurs ont travaillé étroitement avec le personnel de la prison afin de pouvoir adapter leur enseignement à un environnement aussi spécial et en fonction des besoins éducatifs des étudiants. Nous présentons le processus d'évaluation des étudiants qui a forcément été limité par les règlements de la prison. Finalement, nous présentons les résultats de l'évaluation qu'en ont faite les partenaires et les instructeurs et qui mentionne les écueils, les défis et les possibilités. Le Département des services correctionnels s'est montré très satisfait du programme et a demandé qu'on le rende disponible aux autres établissements de l'État.

Mots clés : service de formation forestière, formation en milieu carcéral, sud des États-Unis, arboriculture, compétences professionnelles, besoins spécifiques

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Introduction

The United States correctional system is an acute societal issue. The nation has consistently experienced the largest incarceration rates in the world with the prison population nearly tripling between 1980 and 2014 (Bureau of Justice Statistics 2015, World Prison Brief 2016). Further, recidivism is a common problem while correction facilities and programs, including probation and parole, cost tax payers around $74 billion in 2007 (Kyckelhahn 2011, Davis *et al.* 2013). The growth and costs of the prison population have focused attention on the educational characteristics of the prisoners. Adult inmates have lower levels of educational attainment than the general population with over 40 % of incarcerated individuals not completing high school (Harlow 2003). Besides lower levels of educational attainment, prisoners often lack vocational skills and a consistent history of employment (Davis *et al.* 2013).

Prison education programs seek to address this problem by developing skills for post-prison workplaces (Davis *et al.* 2013). Such programs have been shown to reduce recidivism, have a calming effect on the prison community, and improve job outlook upon release (Coley and Barton 2006). Ewert and Wildhagen (2011) suggest prison education programs may reduce recidivism rates by changing behavior through improved cognitive skills and socialization towards society norms that reject criminal behavior. Moreover, education programs have reduced incarceration costs by four to five dollars during the first three years post-release for each dollar investment in prison education (Davis *et al.* 2013). In addition to literacy, General Education Development (GED), and college courses, a common vocational program topic is horticulture, with gardening programs having been practiced in U.S. prisons since the 1800s and Cooperative Extension leading the effort in several states (e.g., Reld and Dorn 1995, Robinson and O'Callaghan 2008). Less common are programs covering forestry and arboriculture topics.

This article describes a forestry extension education program to low-risk male inmates in the Mississippi correctional system. The project highlights collaboration between Extension and the Chickasaw County Regional Correctional Facility (RCF). The overall goal of the project was to create awareness among inmates regarding various forest management and urban tree care topics. Specific learning objectives included participants: (1) gaining awareness about potential employment opportunities; and, (2) broadening their knowledge base. Additional project objectives were to: (1) cultivate a partnership between Extension and the Mississippi Department of Corrections; (2) test a forestry educational model for a correctional facility audience; and, (3) provide a distraction from the daily stresses and challenges of prison life. We provide this article with the hope that Extension professions will consider prison inmates as a potential non-traditional audience for natural resources outreach education.

Procedures

Institutional collaboration was essential to the success of the project. The project was initiated by the County Extension Agent and the Correctional Facility Warden. The Warden suggested forestry and arboriculture, which involve outdoors work, might appeal to inmates. The County Agent then contacted specialists in forestry and arboriculture to design a curriculum. Initially, Extension specialists designed a draft curriculum and learning objectives reviewed by the County Agent, Warden, and Prison Education Officer who suggested revisions based on the unique context and needs of the audience. Each curriculum topic was delivered during one weekly period lasting one to two hours. The following topics were addressed during the course: (1) forest management planning, (2) site preparation, (3) planting pine trees, (4) natural regeneration, (5) harvesting and best management practices, (6) financial considerations, (7) timber marketing, (8) pine plantation thinning, (9) prescribed burning, (10) taxation, (11) logger safety, (12) wildlife habitat, and (13) arboriculture.

Instructors were required to follow standard security protocol and advised to treat inmates with respect, but to avoid over sociability as inmates are adept at manipulating associations. The Warden required inmates to be on their best behavior in exchange for the privilege of participating in the educational program. Participants who broke this rule were expelled from the course. Each class was video-taped for later viewing by state correctional facilities.

Three modes of evaluation were employed. The Institutional Review Board determined the evaluation process assessing the effectiveness of educational outreach in a correctional facility did not qualify as human subjects research (45 CFR 46.102[f]) and therefore did not require IRB oversight. Inmate participants were verbally evaluated on the prior week's class before starting each class. Weekly written evaluations were not distributed because, as the Warden explained, such an approach could contribute to instability in the classroom if prisoners viewed it as overly formal. It is important to remember that some students may have been reticent to complete formal evaluation due to previously negative classroom experiences marked by feelings of failure. Instead the County Agent, who was familiar with each topic, would ask a set of five to ten multiple choice knowledge questions to which inmates would respond by raising their hands. The County Agent tallied responses and participant names were not recorded.

At the end of the course, an anonymous written evaluation was administered to 16 students. On a five-point scale from very poor to excellent, the evaluation measured program assessment, including self-reported usefulness of information, quality of instruction and materials, and perceived change in knowledge. Additional questions addressed perceived likelihood of working in forestry in the future, need for more educational classes, likelihood of attending educational classes, and an open-ended question asking for course suggestions. We opted for a limited number of questions to mitigate the burden placed on participants. Self-reported results on the final course evaluation must be interpreted with caution since inmates may be influenced by their perceptions of responses acceptable to facility managers who were present during classroom evaluation and who were provided an evaluation report compiled by the County Agent.

A third set of evaluation data was collected through interviews with the curriculum committee. Interviews are a common and expeditious method of program assessment, particularly among key participants (Luloff 1999). Ten individuals involved with the project, including eight instructors and two prison staff, were interviewed. A questionnaire guided the interviews through a series of open-ended questions. The authors conducted the interviews generally lasting between fifteen and twenty minutes. Interview questions included: (1) Did you think your lecture was successful? (2) How did the subjects react to the information you provided? (3) Were there any problems? (4) Is there anything you would do differently in the future? and, (5) Is there value in providing this type of program? This article reports results from the latter two evaluation methods using the interview questions as a guiding framework.

Results

Did you think your lecture was successful?

Overall, project personnel believed lectures accomplished the learning objectives. Facility managers (the warden and education officer) were thrilled with the program and requested future courses, and were satisfied with the outcome of the program. Several instructors noted students were exemplary and, in some ways, were more attentive and appreciative than traditional audiences. One instructor said:

> *"Yes [my lecture was successful], especially my first one. The inmates asked lots of questions and appeared interested and engaged. They thanked me profusely for giving them the books as reference."*

However, this instructor also suggested students appeared fatigued during his second presentation, the last of the course.

Similarly, the final course evaluation results suggested high student satisfaction with the course. Sixteen (100 %) students rated the quality of the speakers as very good to excellent. Students also tended to rate the material highly, with 13 reporting very good to excellent. As well, students reported a substantial change in knowledge. An instructor of wildlife management and recreation noted some prior knowledge when he provided a lecture; however, only one student reported very good knowledge of the topics in general prior to the course. At the course's conclusion, six of seven respondents said they had very good to excellent knowledge. What is important here is not actual knowledge gained, which was not measured, but students' perception of change because this relates to self-esteem and transformative process (Mezirow 2000).

How did the subjects react to the information you provided?

Project personnel, including facility managers, were impressed with students' enthusiasm for learning. Without exception, project personnel reported that students "…enjoyed the lectures and soaked up the information like sponges." One instructor recalled, "A couple [students] had questions on career opportunities. I mentioned outfitters as guides, or state parks as grounds keepers." A harvesting operations instructor said students related to machine operation even though they were not familiar with the specific logging equipment.

Commenting on how word of the program spread throughout the institution, facility managers reported "… there [was] a lot of interest from those that have not yet attended." Underscoring this, managers also said most students seemed to have thoroughly read the material before attending classes. This is important since there is a tendency for inmates to have possessed few educational inclinations prior to their prison experience (Harlow 2003).

Were there any problems? If so, what?

Project personnel did not describe any major problems. Facility mangers did not report problems and were pleased the program was completed without serious issues. Other than instructors' initial reluctance at the idea of prison programming, lecturers said "Attendees were conscientious of my time and well-behaved." The only major weakness mentioned—not an operational problem—was concern that the program would not result in actual post-incarceration behavior change. The instructors, who normally work with the general public, base their programs on influencing knowledge and behavior change in contrast to the less tangible objectives of this project. For their part, eight of 16 students reported excellent chances of working in the forestry/tree care industries in the future, while two of 16 reported such employment unlikely. Six of 16 said their chances were neither good nor poor.

Is there anything you would do differently in the future? If so, what?

In response to this question, facility managers suggested additional classes and readings. Facility managers clearly believed the program was appropriate for the audience in terms of time and difficulty. Like the instructors, they would have preferred hands-on demonstrations, but recognized this would be "difficult due to inmate supervision requirements." In response to this challenge, one instructor had the idea of utilizing videos of machine operation, which he thought would get students' attention. Another suggested having a field day while another advocated a work-release program to give students a "vision of how to do things on the ground." Demonstrations may be limited to those students facility managers believe are deserving of such activities.

Is there value in providing this type of program?

Project personnel expressed mixed responses to this question. Again, responses may be influenced by comfort level with a non-traditional audience, delivery strategy, and project objectives. One instructor noted the difficulty of bearing in mind that the program was not only to increase knowledge and awareness of potential employment opportunities, but also to enlighten inmates and moderate a tense environment. Thus, when one instructor said the value is "limited and not the optimal impact", he could have overlooked the less tangible benefits of prison education. It is important to note that the instructors who were most reticent to participate in the project were also most likely to perceive limited value in the project. These results underscore the importance of having full buy-in from instructors, which also improves instructional quality.

Another instructor indicated that, while forest management *per se* may have limited practical value since it requires a two-year degree and many employers may be hesitant to hire ex-inmates, logging may be a more appropriate option. This instructor suggested more emphasis on logging, chainsaw safety, and best management practices in future programs. A harvesting operations instructor disagreed. Although he thought the project was valuable, he noted significant barriers due to real and perceived liabilities associated with hiring ex-convicts. He thought a work-release program with support from the State and insurance companies would have the best chance at helping ex-inmates succeed in the logging industry.

Another instructor stated arboriculture was well-suited for ex-inmates and the State did not prohibit them from becoming tree surgeons and landscaping professionals. In addition, an instructor believed there was value in making inmates aware of the Extension program as a post-prison resource. After all, Extension provides knowledge and skills in a number of subjects besides forestry. This instructor also noted the training could be beneficial in ex-inmates' future outdoor recreation activities. Finally, one facility manager noted "some of the inmates [planned] on using this information to manage family land and [obtain] employment upon release."

Three questions on the final evaluation addressed the extent to which students valued the program. Only eight of 16 students rated their chances of working in forestry as very good or excellent, while three responded with poor to very poor. Still, 15 students said they wanted more forestry classes with one student noting "[We are] very needful for more classes!" and another student commenting, "What I like: [the course] gave me more knowledge of how important trees are." A third student wrote, "I enjoyed everything about this class. It was one of the best I've been to... The best thing was multiple speakers giving us greater diversity." Although many students appreciated the program, several were critical of the lecture format and would have benefitted more from hands-on activities.

Finally, 15 students stated the chances of attending other educational sessions were very good to excellent. Suggestions for education topics included business management, basic computer skills, hair styling, small engine repair, basic college courses, culinary, bee farming, and many others. Outdoor recreation, including guiding and game management were common suggestions for future programs. These results suggest this group of inmates desired to learn and had potential for transformative behavioral change.

Conclusion

Referring to a Rikers Island Prison Complex horticulture program, James Jiler (2009: 185) acknowledged that, "On its own, [the program] is not a panacea for the huge challenges facing the criminal justice system either in New York City, the state, or country." However, given the costs of prison-based punishment and reform, the existing concept of the correctional facility must be reconfigured as a benefit to society instead of a resource sink. Our experience teaching forestry and arboriculture in a Mississippi correctional facility suggests Cooperative Extension is ideally positioned to address this challenge.

Forestry and arboriculture are educational options inmates across the nation may find interesting and relevant as potential post-release employment. A lack of hands-on experience was a limitation of this program; however, future opportunities may include activities such as establishing a nursery, tree establishment and pruning, and work-release. Undoubtedly, tree care, nursery management, and outdoor recreation are natural resource training topics that may be best suited for inmates with limited education and which would increase their employability. Such topics serve as opportunities for Extension professionals interested in providing correctional facility education. Regardless, this pilot program suggests that natural resources programming is relevant and valuable. The Department of Corrections agrees, and has requested programming to facilities across the state. Continuation of this program would benefit from measuring long-term impact on participating inmates following release, possibly through the parole system.

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