Improving Forest Operations Management through Applied Research

Mark Brown, Martin Strandgard, Mauricio Acuna, Damian Walsh, Rick Mitchell

Abstract – Nacrtak

A great challenge of applied research is translating results into industry innovation. Increasingly, forest managers do not have the capacity to interpret research results but prefer to be presented with tools based on the research results that can be readily implemented. The Cooperative Research Centre (CRC) for Forestry, based in Australia, has focused on delivering research results to industry partners in novel ways that can be easily applied in the field.

This paper discusses six approaches taken by the CRC to help transfer applied research results to industry, including basic benchmarking curves for feller-bunchers, a toolbox for operational machine evaluation, a productivity model, a method to predict productivity with existing data, a guide for effective use of onboard computers and an optimised transportation planning tool. For each approach the paper will discuss how these approaches were developed and applied with industry collaboration.

Keywords: innovation, implementation, efficiency, operations management

1. Introduction – *Uvod*

When working in the field of applied forest research, particularly collaboratively with industry, presenting results in a way that industry can readily make use of is as important as ensuring quality and relevant research. A classic example is Skogsforsk, a world leading applied forest research organisation based in Sweden, whose mission is to supply applicable knowledge, services and products to enhance the competitiveness of Sweden's forest industry. Skogforsk's focus on industry collaboration and delivering research results in a usable form for industry has decreased real harvest costs in Sweden over the past 20 years, with tools like FlowOpt and applied new work methods adapted to new technology (Fryk and Radstrom 2011). To provide results in a usable form to drive innovation, it is necessary for the research provider to understand the value their industry can add to research knowledge, issues of change management and the innovation process. Translation of research results to innovation requires effective communication to industry to allow both the research provider and industry to play active roles in implementation.

Private industry is one of the most effective and valuable avenues for science to disseminate its knowledge more broadly within society. Industry is motivated to satisfy its customers' expectations of good value products and services to remain competitive and can be very effective at converting research knowledge to useable products and services (Cribb and Hartomo 2002). Research can also assist with development of more cost-effective delivery of existing products and services.

Implementing research inevitably involves making change within an organisation. Effecting change requires that management has to understand and believe in the projected impact of the change and effectively communicate that to all involved or impacted (Grover et al. 1995). This management-level understanding can be facilitated by having all stakeholders actively engaged through the research process (Dentoni and English 2011). This can be particularly effective for a small focused industry segment with a clear set of influencing variables, but difficult to do effectively for a broader industry group subject to a wider range of influences.

For the broader industry group, the experience of the CRC for Forestry has been engaging stakeholders as much as possible in setting the research direction, within the bounds of »*good research*«; it is valuable to ensure relevance, but needs to be supported by creative delivery of the research results to facilitate uptake. Providing a simple report often locks the results into a fixed set of assumptions that may not be directly applicable to a specific company and limits trust in the results. Adapting the research results into flexible transparent tools for industry can facilitate understanding of not only the actual research results but, more importantly, how the research results apply in their particular case and what the projected impacts will be within their business.

1.1 CRC for Forestry: the context of collaborative research in Australia – *Centar za istraživanja u šumarstvu: pozadina istraživačke suradnje u Australiji*

The CRC concept program is funded by the Commonwealth Government of Australia to facilitate a collaborative approach between research providers and industry. Through a competitive process an industry group, representing a significant portion of the national industry, comes together with research providers to develop a research program to address particular issues that are common to, and will help improve the competitiveness of, the Australian industry, and more specifically the collaborating partners. A CRC has defined time and resources to meet a set of objectives that are agreed and managed by all the partners. Where an ongoing need for a sustained research effort is identified in the area covered by the CRC, an ongoing institute can be established based on the foundation created by the CRC and its industry partners.

The CRC for Forestry is a very successful CRC currently nearing the end of its third seven-year round of funding. In an independent third year review of the CRC for Forestry it was found that key outputs have or have the potential to deliver in excess of 80% internal rates of return (IRR) for the partners (Agtrans 2008). The success of the CRC for Forestry is further highlighted in its application for a five year extension submitted this year, where more than 80% of the forest industry in Australia are supporting the bid and industry contribution to the research program is increased. Building and maintaining strong industry and Commonwealth support has required that the CRC's research is not only world standard, but also relevant and applicable »on the ground«. This has always involved strong and regular interaction with industry and in recent years a greater focus on how the research results are presented to industry, with greater direct interaction and development of tools that fit their management needs and support uptake.

This paper explores six case studies of delivering collaborative research results from the CRC for Forestry through different tools to facilitate their use for innovation within industry. The cases show how the approach of developing a tool, in addition to formally reporting results, has facilitated industry uptake. It is also shown that the tool need not be particularly complex to effectively demonstrate research results and meet industry needs. Where tools are sufficiently mature and have been used in operational settings by industry, and where the industry partner has been willing to share their results, the impact achieved from the use of the research is noted.

2. Cases – *Slučajevi*

2.1 Managing productivity – benchmark production curve for feller-bunchers *Krivulje proizvodnosti za »feller buncher«*

2.1.1 Background and research – *Pozadina istraživanja*

Many studies have shown feller-buncher productivity to be highly dependent on average tree size (e.g. Gingras 1988, Visser and Stampfer 2003). Other important factors include tree spacing (Long et al. 2002), slope (Oliveira et al. 2009) and undergrowth density (Granskog and Anderson 1981). Productivity data (m^3/productive machine hour (PMH)) from

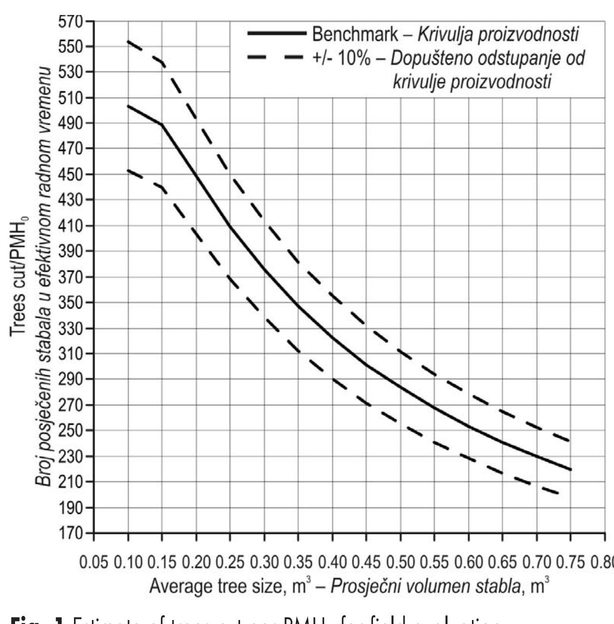

Fig. 1 Estimate of trees cut per PMH_0 for field evaluation
Slika 1. *Procjena broja posječenih stabala pomoću efektivnoga vremena rada za vrednovanje na terenu*

seven short-term studies of feller-bunchers clearfelling *E. globulus* plantations in Western Australia, and from six published overseas studies clearfelling various species, were plotted against average tree size (m^3). Only hot saw and shear head feller-buncher results were used. All delays were excluded (PMH_0). PMH_0 productivity is preferred, as it is easiest to collect in the field by users of the benchmark. A curve fitted to the data from the 13 different field studies gave a good fit (r^2_{adj} = 93%). Estimated trees cut per PMH_0 was derived from the regression and plotted against average tree size (m^3). Lines at ± 10% were added for guidance when using the benchmark curves as shown in Fig. 1. With a strong relationship presented in the curve, armed only with average tree size and a watch, managers and machine owners can quickly determine if the machine is operating at an expected level and take action where appropriate.

2.1.2 Strategy for transfer to industry – *Strategija prijenosa znanja industriji*

The feller-buncher benchmark curves were distributed to harvest contractors and other potential users by:

⇒ CRC Bulletin – key research findings and the benchmark curves. Distributed to client organisations (Strandgard and Mitchell, 2010),

⇒ Meetings with client organisations,

⇒ Article in the Australian Forest Contractors Association newsletter, 23 November 2010 (*http://www.afca. asn.au/afca%20log/Log_23_November_2010[1][1].pdf*),

⇒ Distributed directly to harvesting contractors using email or in face-to-face meetings.

2.1.3 Implementation by industry and impact *Primjena u industriji*

Contractors and machine operators use the benchmark curves by estimating average tree size from estimates of merchantable volume per hectare and stems per hectare provided by the forest manager. Average tree size is then used to estimate the expected number of trees cut per PMH_0 from the benchmark line. This figure is compared with actual performance to identify and remedy underperformance and reward over-performance. For a typical West Australian *E. globulus* stand, a feller-buncher operating 10% less productively than expected would cost ~ 40 000 $ more per year to cut the same volume of wood as a machine operating at the benchmark rate. Requests have been received from both contractors and forest managers to have similar curves produced for other common machines.

2.2 Equipping operations to do effective evaluation – Machine Evaluation Toolbox *Alat za procjenu proizvodnosti rada i strojeva u šumarstvu*

2.2.1 Background and research – *Pozadina istraživanja*

Being able to effectively measure and understand machine performance is critical to having efficient mechanised forest operations, but the need for machine evaluation is infrequent and rarely a core skill for managers. The challenge for time-constrained managers and contractors is maintaining their basic skills and a consistent approach when the need arises for machine evaluation to support important management decisions.

Initially the CRC for Forestry research team created a standard framework for machine evaluation in Australia, based on the recognised international framework from the International Union for Forest Research Organizations (IUFRO) (Bjorheden et al. 2000), to guide the research program and ensure internal consistency. What became immediately clear from the introduction of the framework was that the industry would need assistance to interpret and implement it to maintain the consistency of approach established by the CRC for Forestry. To meet this need a series of workshops were provided to the industry.

Feedback from the workshops was that they provided an excellent introduction, but industry participants typically did not have machine evaluation as a primary focus when they returned to their jobs. When the need for evaluation arose, the workshop knowledge had been lost and needed to be refreshed. Based on this feedback the CRC for Forestry Machine Evaluation Toolbox was created, providing industry with instructions for four common evaluation methods, field forms, basic calculators and report generators for the most common forest machines. The tools are available in a simple software format using intuitive menus to access the appropriate set of directions and tools for a given evaluation on a given machine type. Evaluations done with the toolbox are consistent with CRC for Forestry methods, making the results comparable with research results and benchmarks.

2.2.2 Strategy for transfer to industry – *Strategija prijenosa znanja industriji*

As part of the CRC's collaborative approach to industry the toolbox was directly distributed to industry partners for initial review and was updated based on feedback received. As part of a broader industry engagement strategy, lunch-hour workshops on CRC for Forestry research outputs have been offered to industry partners at their locations for their staff – the machine evaluation toolbox has been the most requested topic. It has also been directly implemented by contractors who co-operated in CRC for Forestry trials and wanted to expand on the trial work.

2.2.3 Implementation by industry and impact *Primjena u industriji*

Though early in its introduction, the toolbox is seeing use within industry to address questions about productivity as it relates to different operating conditions and machine utilisation. Initial use has been limited to contractors seeking to improve specific knowledge for the management of their operations, contract tendering and negotiations.

2.3 Predicting productivity from harvester stem files – *Predviđanje proizvodnosti iz podataka prikupljenih radom harvestera*

2.3.1 Background and research – *Pozadina istraživanja*

Creating a harvester productivity model has traditionally been a time-consuming task using stop watches, or video cameras and data loggers, to estimate harvest cycle times. Model accuracy is limited by the funds and time available.

Harvester productivity studies can be heavily influenced by operator performance differences (Ovaskainen et al. 2004). This effect can be reduced by conducting trials of multiple operators and machines or combining study results to create generalised productivity models. Few such models have been developed (e.g. Nurminen et al. 2006, Spinelli et al. 2010), which reflects the significant time and effort required.

Recently the use of StanForD stem file records generated by single-grip harvesters was trialled by the CRC for Forestry to estimate harvest cycle time. Stem files record the time and date a tree was cut and its log product information. Differences between times recorded in consecutive stem files can be used to estimate cycle time and develop a productivity model. Compared with current methods, using stem files has the potential to rapidly produce productivity models as data are readily available. The drawbacks are that there is no onsite observer able to note unforeseen changes in trial conditions (Nuutinen et al. 2008) and elemental time information is not recorded.

Four trial sites in *Pinus radiata* plantation clearfell operations across southern Australia were used to compare stem file productivity models with those produced using time and motion studies. The stem file data were filtered to remove cycle times with large delays and trees with broken tops and multiple leaders. At all sites, the models produced by the stem file approach were not statistically significantly different to those produced with time and motion studies, which suggests the stem file approach can be applied more widely when stem files are collected under consistent, known stand and site conditions.

2.3.2 Strategy for transfer to industry – *Strategija prijenosa znanja industriji*

The stem file productivity model tool is still under development. The planned tool will import stem files and apply user-selected filters to remove cycle times with large delays and trees with broken tops and multiple leaders. Models will be generated from the filtered data for typical model forms used for harvester productivity models (linear, logarithmic and power). The tool will be distributed electronically through CRC for Forestry networks, workshops and direct interaction with industry stakeholders.

2.3.3 Implementation by industry and impact *Primjena u industriji*

The tool is intended to be used by harvesting contractors to estimate rates and manage operations, by forest managers to plan harvest schedules and estimate harvest costs and by researchers to evaluate harvester performance. Savings are mainly expected from reduced time spent developing models, which may amount to thousands of dollars per model. There may be further savings from increased availability of productivity models, but these are currently difficult to quantify.

2.4 Guide for improved operations management with onboard systems – *Vodič za upravljanje radnim operacijama pomoću ugrađenoga sustava*

2.4.1 Background and research – *Pozadina istraživanja*

Experience in Europe and North America has shown that effective use of onboard computing equipment in forest harvesting machines can produce gains of up to 30% in availability, utilisation and productivity (e.g. Jamieson 2004). In Australia, lack of information about onboard computer capabilities and implementation has been identified as a key barrier to their uptake. The only area where there has been widespread uptake is bucking optimisation in *P. radiata* plantations, which has been driven by the requirements of forest managers.

Results of trials installing and testing onboard computing equipment in Australia have been used to develop a selection and implementation guide.

Users of the guide select their problem or concern from a list and are taken to a description and examples, key points and case studies of the onboard computer(s) best suited to address that concern. Basic steps needed to implement each category of onboard computer including installation; setup and basic information on the use and analysis of the data collected by the computer are also covered in the guide.

An initial study identified a number of onboard computing systems with the potential to improve harvesting machine performance. Three trials were established to test the most promising of these onboard computing systems across a range of Australian forest harvesting systems and forest types (natural forest, *P. radiata* and *E. globulus* plantations). An additional trial was established when the opportunity arose to test a pre-release version of FPInnovation's FPDat (http://fpsuite.ca).

2.4.2 Strategy for transfer to industry – *Strategija prijenosa znanja industriji*

Forest harvesting contractors are the primary intended users of the onboard systems selection and implementation guide, with forest managers as other potential users. The guide was delivered by:

⇒ a series of industry workshops across southern Australia,

⇒ distribution of printed copies of the guide,

⇒ an online, interactive version of the guide (*http://www.crcforestry.com.au/publications/downloads/CRC-Onboard-Computers-WEBLINK-21_031.pdf*).

2.4.3 Implementation by industry and impact *Primjena u industriji*

There is widespread potential to use onboard systems in Australia to identify inefficiencies in harvesting systems and to better understand baseline performance to enable more accurate harvest rate setting. One of the case studies used in the development of the guide identified savings of approximately 100 000 $ per year from the application of onboard computing systems, for an operation that represents less than 0.5% of the annual harvest in Australia, while another case study (unpublished) determined the main delay causes in an in-field chipping operation.

2.5 Accurate operational predictions of productivity and cost – ALPACA *Operativno predviđanje proizvodnosti i troškova pomoću sustava ALPACA*

2.5.1 Background and research – *Pozadina istraživanja*

While several comprehensive productivity and costing models have been developed for specific regions, few are available in the literature and on the Internet. In Canada, FPInnovations developed ProVue (FPInnovations 2005), based on 30 years of field studies, to help contractors pick the best harvesting system for unique forest conditions or to predict operating productivities when they move to new sites. Contractors search for productivity and cost data by specifying the components of a harvesting system and by terrain conditions, area and study period. In South Africa, the Department of Forest and Wood Science (University of Stellenbosch), in conjunction with the Forest Engineering Programme (Institute for Commercial Forestry Research South Africa) developed the South African Harvesting & Transport Systems Costing Model for both large and emerging contractors (University of Stellenbosch and Institute Forestry Research South Africa 2009). In the US, the Forest Operations Research Unit has developed two spreadsheet-based tools: the Machine Rate Calculator, to analyse system balance, production rates and cost, and the General Ground-Based Harvesting Systems Analysis to estimate total system cost based on stand characteristics, felling, skidding, processing, loading, roads and hauling, and operational factors (USDA Forest Service 2008).

The current version of the Australian Logging Productivity and Cost Assessment (ALPACA) tool was developed as part of a collaborative project between the CRC for Forestry and Oregon State University. It is based on more than 200 production studies on felling, yarding, processing, chipping and loading, and it provides two types of analyses: harvesting system forecast and single machine. In addition to data on times for extraction cycles, delays, etc., data were also assembled on felling breakage, average piece size, payloads, etc. for various types of terrain and felling patterns. Harvest systems include cut-to-length at stump or at roadside, in-field chipping with debarking at stump or at roadside, and cable-logging operations. Using the research results at the core of the tool it predicts daily production, rate per tonne or m^3, total harvesting costs and number of days to log the harvest block.

2.5.2 Strategy for transfer to industry – *Strategija prijenosa znanja industriji*

Industry partners were provided with a brief workshop on the ALPACA prototype to allow them to trial the software and provide feedback for changes and improvements. The workshop consisted of a general description of the tool, the harvest systems included, calculation of productivity and costs, the data inputs required and several demonstrations and exercises with the participants. As the tool is still under development, it has also been distributed to logging contractors and operational staff to get their comments and feedback.

2.5.3 Implementation by industry and impact *Primjena u industriji*

Harvest managers and contractors can use ALPACA to predict harvesting costs and productivity of different systems for specific forest conditions. Inputs are relatively easy to collect and include among others: harvest unit details (e.g. total compartment area), stand details (e.g. merchantable volume), harvest type (e.g. clearfell), species, harvesting system (e.g. cut-to-length) and extraction details. In addition to overall costs and productivity other outputs include daily production costs by activity (felling, skidding, etc.) and number of days to log the compartment. The tool could eventually be used to plan the harvest, match harvesting systems to forest conditions, assess the impact of operational factors on productivity and cost, as a control tool allowing managers to compare actual performance against predicted performance, and allocate logging crews to harvest units.

2.6 Optimised transport and logistics planning – FastTRUCK – *Poboljšanje prijevoza drva i logističkoga planiranja sustavom FastTRUCK*

2.6.1 Background and research – *Pozadina istraživanja*

Several optimal transportation models developed internationally and their corresponding solution approaches were investigated before developing and implementing FastTRUCK. In Chile, a computerised system called ASICAM has been in use since 1990. It is a simulation system embedded with a heuristic solver which produces a complete working schedule for one day (about 100 trucks) in only a few minutes (Epstein et al. 2007). ASICAM has led to reductions in transport costs of between 10% and 20% (Weintraub et al. 1996). In Sweden, Skogforsk developed a system called FlowOpt (Forsberg et al. 2007). The system integrates GIS data with a database and uses a heuristic approach based on a tabu search algorithm. Tests have reported savings of 5% – 20% compared to manual solutions. Other approaches include a Finnish system called EPO that deals with all stages from strategic to operative planning (Linnainmaa et al. 1995) and a solution approach reported in Palmgren et al. (2004). These are all very effective tools, but in many cases their availability was limited to the organisations that developed them or they were not well-suited to address the specific forest transport issues in Australia.

FastTRUCK's first version was developed for in-field chipping operations. It is a Microsoft Windows®-based system developed in Visual C++® and uses inputs from the existing parameters of the transport operation to generate a range of alternatives to determine the optimal (or near optimal) operating scenario. Optimal truck schedules are created by FastTRUCK using a simulator and a simulated annealing algorithm. The aim of the system is to minimise total transportation costs. It considers travel loaded and unloaded time, stood down time and fixed costs. FastTRUCK reports the optimal number of trucks required for the operation, total transportation cost, total volume of chips hauled to dumpers, average truck utilisation, average truck waiting time and average loaded running percentage (travel loaded/total travel distance) while maintaining a user-defined chipper utilisation. Detailed results by truck are exported to MS Excel® and include total time, total cost, trips to dumpers, waiting time, utilisation, running loaded percentage, arrival times at forests and dumpers, and the optimal schedule for one day.

A second version for more complex transport operations (multiple products, truck configurations, destinations, etc.) has been developed in Java® (Eclipse IDE) and is being tested with an Australian company in *P. radiata* plantation haulage operations.

2.6.2 Strategy for transfer to industry – *Strategija prijenosa znanja industriji*

An industry bulletin on FastTRUCK has been published by the CRC for Forestry (Acuna et al. 2010). This report presented an analysis of the factors that affect the transport efficiency of in-field chipping operations. Program industry partners were also provided with a brief workshop on the FastTRUCK prototype to allow them to trial the software and provide feedback for changes and improvements. The workshop consisted of an introduction to timber transport, a description of truck dispatching and scheduling, presentation of some of the potential quantitative and qualitative benefits associated with the adoption of optimisation tools and a demonstration of FastTRUCK for in-field chipping operations.

2.6.3 Implementation by industry and impact *Primjena u industriji*

During 2009 – 2010, the CRC for Forestry worked with an industry partner as it planned a new woodchip export facility in Western Australia. Working with known annual in-field chipping harvest volumes and constraints on truck access times to the port, it was important to determine the required level of infrastructure at the port.

FastTRUCK proved to be a valuable tool in evaluating the required level of receiving capacity at the proposed woodchip terminal in Western Australia. Based on the FastTRUCK results, a significant capital expenditure at the new facility was avoided as it was determined only one dumper would be required rather than the two initially planned. The CRC work also identified that there were additional savings to be made, with the potential for the planned operation to reduce annual costs by 10% through improved harvest and truck scheduling. Applied to the roughly 1 million tonne annual harvest transported from in-field chipping operations around Australia each year, FastTRUCK has the potential to deliver more than 1.5 million $ in annual savings.

3. Discussion – *Rasprava*

These six cases demonstrate a range of strategies used by the CRC for Forestry to lift research results from the page and develop them into tools that are better suited to support industry to engage in the innovation process. In all cases additional effort was needed to translate research results into practical »field-ready» tools. This effort ranged from simply reformatting and amalgamating data to make it easier for industry to receive (e.g. the feller-buncher benchmark curve), to complex software programming (e.g. FastTRUCK). What is important is that the tools were developed collaboratively with end users, to meet industry needs and expectations. Such ownership by end users increases the likelihood of research results playing an active role in industry innovation. The success of the tools rests on choosing the right approach to meet industry need, and ensuring they are fit for-purpose – e.g. not creating complex solutions where a simple one meets the need. This is best managed through ongoing communication and collaboration with industry.

While the level of complexity and resources vary, all six of the tools presented in this paper, with the exception of FastTRUCK, were developed and delivered with commonly available computer desktop tools. In addition to making the development of the tools simpler and limiting resources required, the use of common computer software facilitated the transfer to industry.

It is also important to understand that the development of tools to deliver research results to industry in no way replaces proper reporting of research results. In many cases the research results behind the six presented cases have been or will be published or presented at conferences (Strandgard and Mitchell 2010, Acuna et al. 2010, Strandgard 2009, Strandgard, 2010, Acuna and Ghaffariyan 2011). Reports are an important step to properly document the research and expose the results to proper scrutiny and review by the broader forest research community. While the CRC for Forestry experience has been that reports are not an effective tool to transfer results to industry, they remain an effective mechanism to share results within the research community.

The CRC for Forestry is convinced that the approach of working with industry to present research results in industry-ready, usable tools has significantly increased uptake of our results. This is supported by documented usage and positive feedback from our industry partners. For example, the introduction and use of the feller-buncher benchmarking tool lead to specific requests for the CRC for Forestry to develop similar tools for other common, system--limiting machines such as in-field chippers and harvesters. The onboard system selection and implementation guide was delivered to more than 100 industry stakeholders over six workshops and has lead to supplementary requests to the CRC to assist individual companies implement the technology appropriately to deal with specific needs in their operations. This demonstrates that the objective of this research has been achieved – the guide has initiated the uptake of onboard technology. Only a few weeks after its introduction to industry the machine evaluation toolbox has been the most requested topic of CRC-delivered lunch-hour seminars/workshops. Of the 60 industry stakeholders that have received the tool, more than 90% report they will use it in their work.

While very different in their presentation, complexity and application, what the six cases have in common is they are targeted at a key industry interest or need. All of them hold the potential for significant financial impact for the industry. In 2010, 24.8 million m^3 of timber was harvested in Australia (ABARES 2011) with the CRC for Forestry's partners representing about 80% of that harvest. Changes in utilisation or productivity of as little as 2% gained through the use of the feller-buncher benchmark curve, onboard systems, stem file productivity model, ALPACA or the machine evaluation toolbox, to identify and address an issue in an operation will deliver benefits of between 15 to 20 million $ for the CRC for Forestry partners per year. If the level of improvements that have been reported with early uses are translated across the industry, these benefits increase to more than 80 million $ per year. In the case of FastTRUCK, the second version will be released to all sectors of the industry, and this is expected to reduce transport costs by up to 10% through optimised schedules, providing the potential for more than 25 million $ in annual benefits to CRC for Forestry partners.

4. Conclusion – *Zaključak*

Applied research must consider implementation and innovation as its end objective to sustain support. The most effective approach to achieve this is to have an ongoing, strong collaborative approach with industry end users, and to deliver research results in a form that is ready for use within existing industry structures, to address real industry needs. When presented with effective, easy to use tools, based on quality research and developed specifically for industry needs, large financial opportunities are simply the last motivator to drive change and clearly show the value of research.

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Sažetak

Poboljšanje radnih operacija u šumarskoj praksi i industriji pomoću primijenjenih istraživanja

Velik izazov za znanstvenike jest prijenos znanja i rezultata primijenjenih istraživanja industriji. Štoviše, šumarski stručnjaci na terenu često nemaju vremena za tumačenje rezultata brojnih istraživanja u znanosti te daju prednost već gotovim alatima dobivenim na temelju rezultata istraživanja. Centar za istraživanja u šumarstvu Australije (CRC) usmjeren je na tumačenje rezultata znanstvenih istraživanja te njihovo prenošenje i prilagođavanje kako bi bili lako primjenjvi za prateću industriju. U ovom se radu raspravlja o šest studija koje je Centar prilagodio za prateću industriju.

U prvom slučaju podaci iz 13 različitih područja istraživanja poslužili su za dobivanje krivulje proizvodnosti (broj posječenih stabala u efektivnom vremenu rada stroja) za feller-buncher. Na krivulju proizvodnosti dodane su linije odstupanja od ± 10 % (slika 1) koje predstavljaju smjernice pri korištenju referentne krivulje. Promatrajući prosječni obujam stabla, šumarski stručnjaci i vlasnici strojeva mogu brzo utvrditi radi li stroj na očekivanoj razini proizvodnosti, tj. siječe li dovoljan broj stabala u efektivnom radnom vremenu.

Na temelju povratnih informacija iz industrije Centar za istraživanja u šumarstvu osmislio je tzv. alat za procjenu strojeva u šumarstvu (Machine Evaluation Toolbox) koji omogućuje četiri metode procjene rada za najčešće korištene šumske strojeve, korištenje terenskih obrazaca, izračune i računske operacije te sadrži generator izvještaja. Takav alat omogućuje stručnjacima na terenu brzo djelovanje pri ocjenjivanju proizvodnosti sustava rada i strojeva.

Inače je za izradu modela proizvodnosti harvestera bilo potrebno mnogo vremena, no korištenjem tzv. programa StanForD iz matičnih datoteka zapisa jednozahvatnoga harvestera procijenjeno je vrijeme turnusa rada stroja. U usporedbi sa sadašnjim metodama, koristeći matične datoteke stroja, uvelike je ubrzano stvaranje učinkovitih modela proizvodnosti stroja.

Računalna je oprema ugrađena u pojedine sustave rada te je stvoren vodič za upravljanje radnim operacijama. Korisnici vodiča odabiru problem ili poteškoću na koji su naišli u sustavu rada pa ih program vodi opisu i mogućim primjerima za rješavanje toga problema.

Alat za operativna predviđanja proizvodnosti i troškova (ALPACA) temelji se na više od 200 izrađenih studija proizvodnje te pruža dvije vrste analize: 1) sustav za procjenu sječe i 2) sustav za procjenu stroja. Koristeći rezultate istraživanja, alat omogućuje predviđanje dnevne proizvodnja, jediničnih troškova i vrijeme potrebno za sječu drva.

Za stvaranje rasporeda prijevoza drva korišten je sustav FastTRUCK. Sustav pruža stvaranje rasporeda kamionskoga prijevoza kako bi se smanjili ukupni troškovi prijevoza drva te iskoristio najbolji mogući broj kamiona potrebnih za prijevoz drva u jednom danu.

Tih šest slučajeva pokazuje niz strategija kojima se koristi Centar za istraživanja u šumarstvu kako bi se rezultati znanstvenih istraživanja iskoristili u šumarskoj praksi i industriji. U svim slučajevima bio je potreban *dodatni napor kako bi se rezultati znanstvenih istraživanja iskoristili u praktične svrhe. Važno je naglasiti da su razvijeni alati i programi nastali u suradnji s krajnjim korisnicima da se zadovolje potrebe i očekivanja same industrije. Suočena s djelotvornim alatima, jednostavnim za korištenje, nastalim na temelju kvalitetnih znanstvenih istraživanja te posebno razvijenim za potrebe industrije, velike financijske mogućnosti korištenja tih alata postale su jednostavno zadnji u nizu pokretač promjena u industriji te je jasno pokazana vrijednost znanstvenih istraživanja.*

Ključne riječi: inovacije, primjena, učinkovitost, upravljanje proizvodnjom

Authors' address – *Adresa autorâ*:

Mr. Mark Brown
Harvesting and Operations Program Manager & Industry Engagement Manager
e-mail: mwbrown@unimelb.edu.au
University of Melbourne
CRC for Forestry
Department of Forest and Ecosystem Science
Adjunct Research Fellow, University of the Sunshine Coast
1 Water St., 3363, Creswick
AUSTRALIA

Mr. Martin Strandgard
Harvesting and operations program
e-mail: mnstra@unimelb.edu.au
University of Melbourne
CRC for Forestry
500 Yarra blvd., Richmond, VIC
AUSTRALIA

Mauricio Acuna, PhD.
Harvesting and operations program
e-mail: mauricio.acuna@utas.edu.au
University of Tasmania
CRC for Forestry
Private bag 12, Hobart, TAS
AUSTRALIA

Mr. Damian Walsh
Harvesting and operations program
e-mail: damianw@unimelb.edu.au
University of Tasmania
CRC for Forestry
500 Yarra blvd., Richmond, VIC
AUSTRALIA

Mr. Rick Mitchell
Harvesting and operations program
e-mail: rick.mitchell@wapres.com.au
CRC for Forestry – WAPRES
Level 2, 53 Victoria St, Bunbury, WA
AUSTRALIA

Received (*Primljeno*): July 26, 2011
Accepted (*Prihvaćeno*): September 5, 2011