Specialty Wood Products
Research Partnership

Expert Advisory Panel review of the SWP programme - 2017

Authors: Glenn Howe, Kevin Harding and Andy Buchanan

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FOREST GROWERS RESEARCH

I. INTRODUCTION

1. Overview

The project has many strengths and a few weaknesses (detailed in the body of the report). The main strengths include active industry/research collaborations, strong science, and a large team with diverse expertise. The main weakness is insufficient focus on activities that will have the greatest impact on achieving long-term project goals, particularly related to identifying and developing products for international markets. Research must be based on whole forest systems, each being the full chain from the forest resource, through processing, to products and markets. Thus, we recommend that the project strategically re-evaluate the forest systems included in the project, with the aim of re-focusing activities on the weak links in key forest systems. This will enhance the confidence of growers, processers, and markets in investing in these forest systems. This confidence is critical for substantially increasing the planting of SWP species.

II. RECOMMENDATIONS

1. Strategic recommendations

1. Focus on a smaller number of key projects. Devote 80% or more of project resources on the weak links of only a few of the most promising forest systems. A forest system includes a vertically integrated forest resource, processing infrastructure, products, and markets.

2. Key forest systems focused on international and domestic markets include:
   - Douglas-fir for current markets, OEL, and other engineered products (e.g., LVL, CLT etc.),
   - Non-durable eucalypts for current markets, OEL, and other engineered products (e.g., LVL, CLT etc.), and
   - Durable eucalyptus for vineyard posts, LVL and sawn timber (structural and appearance).
3. Focus more on a single durable and a single non-durable eucalypt species. If this is not possible yet, focus should be on species evaluation across sites, rather than on intensive breeding programs for multiple species and hybrids. <u>Sufficient knowledge of species/site matching is needed before expensive long-term breeding programs are fully implemented</u>.

4. Key projects are those that will increase the confidence of growers and processers to expand the use of specialty species. Confidence will be enhanced by providing information to growers and processers on:
   - Where species and genotypes can be successfully grown,
   - What the characteristics of the resulting plantations will be,
   - What products can be successfully marketed internationally,
   - How the resource will be processed for these products, and
   - What are the markets, wood properties required for those markets, and financial returns?
5. The information described under #4 should be showcased in brochures that compare New Zealand forest products to competing established international alternatives, such as Douglas-

fir from the Pacific Northwest, spruce/pine/fir from Canada and Europe, US southern yellow pine, western redcedar, and hardwoods such as oaks, maple, and mahogany. Similar approaches were used by NZ FRI to successfully promote New Zealand grown plantation radiata pine and Douglas-fir in the 1980's. The Douglas-fir Association has a lot of this information on its website already http://www.douglasfir.co.nz/. Although the information described under #4 is not fully available, work on these outreach publications should begin soon because this will help identify knowledge gaps that could still be addressed during the SWP project.

6. Conduct annual strategic assessments to identify the most promising forest systems (which may change over time). Assign the responsibility of doing this to the Project Manager, working to focus programme strategic direction in consultation with the PSG and TST.

7. Develop business cases for each of the key forest systems (i.e., species and product combinations).

8. Increase focus on processing, investigating new products and markets, and determining the processing needs of those markets. Begin with economical small-scale manufacturing and testing to show the potential for technical improvements (strength, stiffness, durability, etc) before moving to a commercial scale. An increased focus on processing might be facilitated by bringing in new SWP members.

9. For Douglas-fir and non-durable eucalypts, focus on developing high-stiffness products. Focus on improving stiffness via log/product sorting and processing, rather than on within-species genetic improvement (but monitor stiffness for potential long-term declines in breeding programs). Start processing trials now for selected products to begin accumulating valuable experience and data. Because Douglas-fir and eucalyptus species may have different products, these processing trials are expected to be species-specific. Most Douglas-fir sawmills are either sorting individual logs by Hitman, or sorting on the green chain by acoustic testing, so this is already happening.

10. For all species, additional empirical information is needed on species/site matching. Thus, it will be valuable to develop a long-term, SWP-wide strategy for establishing the new (e.g., multi-species) plantations that will provide this information. Incorporate demonstration plantings into this research wherever possible.

11. Develop stronger outreach efforts to deliver project information to non-SWP growers, processers, and domestic/international markets. To meet SWP planting targets, all potential growers and processers should be targeted. This will also develop a critical mass that will benefit current SWP members. Establish demonstration plantings with sufficient scale (e.g., 4-5 ha blocks) to foster industry confidence. To achieve even larger (i.e., industry-scale) demonstration plantings it might be possible to collaborate with regional organizations (e.g., via regional plans) that seek to attract more forest industry to their regions.

12. Increase industry participation in SWP by increasing collaboration by current members, and by attracting new members.

13. Continue to review the key commercial requirements of the plantation resources (e.g., tree age, stem form, wood properties, and piece size) that underpin the profitability of the whole forest system.

14. Get MBIE re-engaged in the programme. Strategic and timely feedback from MBIE is needed to ensure that the programme is delivering to their expectations, or should be refocused.

15. Seek new funding from Australian sources, to be matched by MBIE.

16. Increase collaboration between UoC and Scion.

2. Project-specific recommendations

1. For Douglas-fir, focus on (1) refining breeding and deployment zones (i.e., species/genotype site matching), (2) improving stem form and growth (with and without SNC pressure), (3) making new selections (i.e., speeding the measurement and analysis of genetic test plantations), (4) implementing genomic selection, and (5) developing business cases for promising products, starting with OEL.

2. For the durable eucalypts, focus on (1) species/genotype site matching, (2) directly evaluating the durability of young plantation materials (e.g., is within-species improvement of durability even needed?) and (3) simplifying breeding programs, including focusing on a fewer number of key traits (e.g., by developing economic weights).

3. Research on the non-durable eucalypts falls into two sub-categories: research aimed at establishing new plantations and research on existing forests. For tree breeding and new plantings, focus on (1) species/genotype site matching, (2) simplifying breeding by focusing on a fewer number of key traits (e.g., by developing economic weights). For existing forests, focus on (3) completing the drying research, (4) evaluating the potential for high-stiffness products, such as LVL, and (5) evaluating the potential and economics of OEL.

4. The EAP had lengthy discussions about the cypress work, and did not achieve consensus. The upside is that the cypress work would help engage the farm forest community. The downside is that the cypress work detracts from forest systems that are more likely to meet overall SWP goals. In any case, it is important to complete the ongoing cypress work, but the project should carefully consider whether cypress should be one of the focal forest systems going forward. The amount of effort devoted to cypress (i.e., versus other recommended activities) should be carefully considered at the upcoming workshop on cypresses to be held in October 2017.

5. Focus on achieving much greater long-term, project-wide integration and collaboration on species/site matching. For example, two separate proposals to the SFF on species/site matching submitted by UoC and Scion may prove counter-productive. A single, strong, and collaborative grant proposal would be better.

III. PROJECT EVALUATION

1. Project organization and management

Overall organization and management

The organization and management of the project is generally strong. The roles and memberships of the various teams are clearer than they were last year, there is an engaged project manager, and the scientific teams are generally strong. However, we could still use on overall summary document of team members with roles and contact information listed.

We see a need for more purposeful and frequent strategic planning to allow programme directions and resources to change as needs arise. This is particularly important for long-term projects such as this. Thus, we recommend that annual *strategic* assessments be conducted to identify the (1) most promising forest systems and (2) weak links in need of research (which may change over time). The responsibility for accomplishing this should be delegated to the Project Manager, who should work to focus programme strategic direction in consultation with the PSG and TST.

Funding and collaborations

One of the main reasons for lack of business plans and inadequate processing research appears to be lack of money. In addition to refocusing existing SWP resources, we recommend that SWP pursue additional collaborations and funding. Any additional funding may be able to attract matching funds from MBIE. Possible avenues include the following:

- **Other manufacturers of engineered wood.** It may be difficult to bring in manufacturers other than JNL at this stage, but this may be possible if done soon, provided that the costs and benefits are clear for everyone.
- **Nelson Pine Industries.** Nelson Pine has been involved in eucalypt LVL trials with DFI (and hosted a site visit on 20 April), so it is surprising they are not partners in SWP. They would be complementary to JNL.
- **Xlam or other CLT manufacturers.** These could also be approached.
- **Forest and Wood Products Australia.** The most obvious missing organization is FWPA in Australia. If the target markets for new wood products include Australia, then FWPA should be investing in SWP. Also, processing and drying work undertaken by the SWP will have relevance in Australia so meets FWPA's core goals of some of their Australian forest industry funders.
- **Trans-Tasman markets and processors.** For Australia, there is an opportunity to connect with Trans-Tasman markets and Trans-Tasman processors. Australian manufacturers will benefit from double leverage if their contributions are first matched by the federal government, and then by MBIE.
- **Others.** Other possible industry partners include adhesive suppliers, manufacturers of CLT (XLam in Nelson), and manufacturers of glue laminated timber (glulam). The forestry partners in Southland should engage with local sawmillers or glulam manufacturers who are looking for new products and new markets.

2. SWP strategy

Forest system (forest resource, processing infrastructure, products, and markets)
As used in this report, the term ***forest system*** refers to the full chain from the forest resource, through processing infrastructure, to products and markets.

The SWP programme has paid insufficient attention to the whole forest system. Most of the effort has been on the forest resource (e.g., tree breeding, insect resistance, etc), with some work on wood properties, but not enough attention has so far been devoted to possible final products and markets.

Forest resource

- Douglas-fir tree breeding is strong, but *Eucalyptus* tree breeding could be simplified to obtain greater genetic gains in key traits in a shorter time.
- Empirical species/genotype site matching (i.e., field tests) should receive much more attention.

Processing infrastructure
Our only serious concern about overall organization and management is in the processing area. We note the following points:

Processing needs a champion. We do not see anyone in the SWP team pushing the boundaries of what might be possible in the processing space, backed up with an R&D plan and business cases for the target markets. The only published research on processing appears to be the two OEL trials on Douglas-fir and *E. nitens*. OEL may fill a minor gap for marketing of small logs, but it will never be a high value or high-volume export product.

As the only major processor in the SWP partnership, it is essential that JNL be driving stakeholder input and collaboration. JNL did not attend the SWP review meetings because they were busy doing full-scale peeling trials of *E. fastigata*, but the connection between that work and SWP activities has not been made clear. The EAP has not been shown sufficient detail of the makeup and responsibilities of the industry/research team for wood engineering and processing. It appears that this research team would benefit from additional capabilities and skills, which may require additional funding (e.g., a possible change in strategy/focus).

Manufacturers will be more likely to do full-scale trials if they have the results of small scale manufacturing and testing that show the potential for technical improvements (strength, stiffness, durability, etc) which could lead to new market opportunities. The small-scale manufacturing and testing can be best done at universities or research laboratories.

A suggested cost-effective option would use university student labour, if the right students, projects, and supervision can be found. Possible UC student projects include (1) engineering and wood science students working on properties of new timber products and (2) MEM (engineering management) students working on markets and business cases.

Products and markets
All R&D should be more market focused. There needs to be analysis of international markets, and products to meet those markets.

OEL is the only SWP product that has received much attention. OEL is stud- and joist-sized glued timber that will compete with solid sawn timber for house framing. JNL are successfully producing LVL (J-frame) to compete with sawn timber in this market, but they are not involved with OEL (OEL is a competitor in the same market). No major engineering research is required here. SWP researchers should monitor the technical and economic success of any new commercial or pre-commercial OEL manufacturing plants as they are established.

LVL has been studied, but the SWP goals for stiffness (MoE) have not been defined. High stiffness LVL will enhance market opportunities for mid-rise timber buildings in NZ and many overseas markets. Most current LVL production (from radiata pine) achieves stiffness values from 8 to 11 GPa, with top quality logs producing 13 GPa. One mill produces a small quantity of 16 GPa LVL, for which they charge a premium price. LVL from new species should target the upper end of this range. A stiffness value of 20 GPa should be the long-term goal for LVL from durable eucalypts.

With regard to other products, JNL have three factories in New Zealand that make LVL, strandboard, plywood, and triboard. Except LVL, it appears that none of these products has been considered. Other possible products include Cross Laminated Timber (CLT) and glue laminated timber (glulam).

Business plans

The goal of MBIE funding was to develop and grow international markets, not domestic markets. Thus, business plans should focus on overseas markets. SWP should identify demand for specific products in overseas markets that NZ can supply at a competitive price. For each forest system to be financially successful, markets must be found for close to 100% of the harvested fibre, from low value products (biomass, fuel, woodchips), to high value products (sawn boards or engineered wood products). This will probably require a combination of local, NZ domestic, and international markets. These requirements must be included in all business plans.

3. Outreach

Outreach should focus on developing confidence in the target forest systems. Demonstration plantings would be valuable in areas where the species perform optimally. Then, it will be useful to prepare and distribute brochures that compare New Zealand forest products to competing and established international alternatives, such as Douglas-fir from the Pacific Northwest, spruce/pine/fir from Canada and Europe, western redcedar, US southern yellow pine, and hardwoods such as oaks, maple, and mahogany. Similar approaches were used by NZ FRI to successfully promote radiata pine and Douglas-fir in the 1980's. Dave Cown (retired Scion wood quality science leader) should be consulted to learn from their experience. Although the information needed for these brochures is not fully available now, work on these outreach publications should begin soon because this will help identify knowledge gaps that could still be addressed during the SWP project, and will need to be scheduled well in advance to complement but not detract from current SWP priorities.

4. Douglas-fir

Douglas-fir is one of the most promising forest systems for New Zealand, and thus deserves substantial effort.

Forest resource

The forest resource for Douglas-fir is well established. Additional species/genotype site matching would be beneficial to refine breeding zones and gain more experience with its performance outside of its current planting areas. Because of environmental heterogeneity, the development of breeding zones is a very positive addition. However, it is probably important to refine these breeding zones to take account of elevational/climate variability, particularly on the South Island. It would be good to carefully assess climate predictions for New Zealand and refine breeding zones for Douglas-fir based on this information. It is likely that additional breeding zones could be used to enhance the performance of Douglas-fir.

Operational plantations and genetic trials often exhibit very poor stem form because of ramicorn branching. Because the poorly formed trees are often healthy, this might be caused by summer rains. In the Pacific Northwest, summer droughts limit the second flushing that is often the cause of ramicorn branching. Thus, breeding programs should focus breeding efforts on improving growth and stem form almost exclusively. That is the best way to achieve productivity rates closer to radiata pine. Issues with Swiss Needle Cast (SNC) are best addressed by selecting for growth in the presence of SNC, but foliage retention might be a good addition. It would be good to see what the genetic correlations are between these traits, and whether gains can be improved by using a selection index. In any case, it is important to establish enough plantations in heavy SNC areas to facilitate selection of tolerant genotypes. Based on experience in the PNW, resistance to SNC is not a realistic goal. Wood stiffness should not receive much attention because that will reduce gain in growth and stem form. Douglas-fir is known for acceptable stiffness, but lacks the productivity of radiata pine, so improved growth is key. Over the long term, however, it would be good to monitor wood stiffness (using acoustic approaches) to ensure that wood stiffness is not declining over multiple generations. Genomic selection is a promising approach for improving gains in target traits. Finally, because of the availability of excellent genetic tests (i.e., tests with many families that are at or beyond optimal selection ages); new selections should be made as soon as possible by speeding the measurement and analysis of these tests. It is great to see that this will be moving ahead aggressively this winter.

Products and processing infrastructure

Because trees are available now, considerable effort should be devoted to processing trials. This will lead to the accumulation of valuable experience and data. Douglas-fir thinnings should be suitable for OEL, and larger trees may be valuable for framing lumber, CLT, or LVL (as in the PNW). However, the business cases for these products and markets have not been thoroughly evaluated. This is a high priority. These business plans are important for encouraging investment in processing facilities and new plantations.

Markets

Douglas-fir is more desirable than radiata pine in some markets because it is better known, stiffer, visually more attractive, and slightly more durable. Marketing studies and business plans are necessary before any more engineering studies are done on Douglas-fir.

Summary

In summary, for Douglas-fir, focus on (1) refining breeding and deployment zones (i.e., species/genotype site matching), (2) improving stem form and growth (with and without SNC pressure), (3) making new selections (i.e., speeding the measurement and analysis of genetic test plantations), (4) implementing genomic selection, and (5) developing business cases for promising products, starting with OEL.

5. Non-durable eucalypts

For the nondurable eucalypts, research is urgently needed on the use of existing stands of *E. nitens* for high value products. This is because wood is now being chipped for export, whereas value could be added through further processing. As for Douglas-fir, the focus should be on developing high-stiffness products, which should be accomplished by improving stiffness via log/product sorting and processing, rather than on genetic improvement. As for Douglas-fir, stiffness should be monitored for potential long-term declines in breeding programs. The research aimed at tree breeding and silviculture for improved growth and form is similar to that for the durable eucalypts.

Trees are available now, so processing trials can start for selected products, to obtain evidence for marketing studies and business plans. Once target products are selected, processing trials will provide valuable experience and data. A start has been made with OEL, but the business case needs to be developed, with a focus on this and other markets. We are informed that JNL is carrying out full-scale peeling and gluing trials with E. *fastigata*, which may contribute indirectly to the SWP programme for non-durable eucalypts.

Processing research should consider the following points. Much of this research also applies to durable eucalypts, but that will come much later when older trees become available.

Sawn timber
It would be valuable to begin processing trials on older trees to examine the potential for producing high quality and high value products. Valuable product characteristics include higher stiffness and colour in older age material.

Basic mechanical and durability testing should be carried out to see if sawn *E. nitens* timber could be used for normal house framing and T&G flooring. The supply of *E. nitens* timber can be used to test building code acceptance for non-radiata species. Research on *E. nitens* should also investigate Australian approaches for drying that use high humidity kiln schedules to minimize degrade. Drying is recognized as a key research area for *E.nitens* because investment in other areas will be wasted if the products cannot be dried with minimal checking, splitting, and non-recoverable collapse degrade. If sawn timber is to be used for CLT or glulam, suitable adhesives and gluing processes are necessary. Australian experience should be used wherever possible.

Laminated veneer lumber (LVL)
It would be valuable to investigate peeling and drying of veneers from young trees, and gluing them together to produce high stiffness LVL from single species or mixed species veneers. LVL studies should include X-banded LVL, to reduce splitting, to improve stability, and to allow stronger fastening systems. Drying and gluing should follow Australian experience, and fungicides and insecticides in the gluelines should be investigated.

A spindleless lathe could be used to get high recovery of veneers from young trees. Recent commercial scale experience with spindleless lathes is available in Australia at Ta Ann, Tasmania (https://www.taanntas.com.au/) and Big River Timbers in Grafton, NSW (http://bigrivergroup.com.au/). Rob McGavin and his colleagues at the QLD Salisbury Research Centre (QLD Dept of Agriculture and Fisheries) have worked on projects with both of these firms (e.g., they helped Big River acquire their spindleless lathe). QLD has also undertaken gluing research with refractive species, and has the capacity to test glue bonds.

6. Durable eucalypts

Durable eucalypt forest system

The durable eucalypt forest system looks very promising for domestic markets. There seems to be a large demand for naturally durable posts for vineyards (particularly organic vineyards). Disposal of broken CCA-treated pine posts is a growing environmental problem, particularly related to disposal. Although complex processing issues are not as large a concern as for other eucalypts, other non-wood posts could also compete.

The main weak links in the durable eucalypt forest system are (1) incomplete knowledge about the in-ground durability of inner and outer heartwood from young trees of the species, (2) knowledge about where the species can be grown productively (species/site matching), (3) unknown risks of insect and diseases, and (4) lack of the quantitative genetic information needed to design cost-efficient and effective breeding programs. Other people are importing seed of naturally durable eucalypts (e.g., unimproved *E. globoidea*), and this could damage the reputation and markets for materials from SWP breeding programs. For this reason, Paul Millen informed us that the NZDFI / SWP products have been trademarked, which is a good idea. Markets for genetically improved and tested durable eucalypts should be monitored carefully.

Breeding programs

Instead of relying on untested assumptions, the breeding programme should focus on the development of breeding strategies based on estimates of quantitative genetic parameters. These include genetic variances, heritabilities, genetic correlations between indirect selection criteria and target traits, selection intensities, and economic weights. If these values are not yet available, genetic gains under alternative breeding strategies should be estimated by substituting values based on the literature and expert opinion, including the use of sensitivity analysis, where appropriate. The EAP looks forward to seeing this kind of information in the future.

The breeding programmes should be simplified to increase genetic gain per unit time. For example, the use of multiple species and hybrids increases the cost and complexity of the breeding program, and makes the species/site matching and insect work more demanding. Although a larger number of species may give more resilience to future unknown pests, this should be balanced against programme complexity. A much smaller number of traits should be considered by evaluating economic weights for each trait. Anytime selections are made, one is implicitly using economic weights, so it would be valuable to make this step explicit. Economic weights can be developed by conducting detailed and expensive studies, or by using expert opinion. By making these economic weights explicit, they also become available to review by other scientists and stakeholders. Selection intensities in seed orchards should be much higher. Based on our knowledge of plant genetics, physiology, development, and regulation of gene expression, the development of an indirect selection assay based on wound response will not be successful for improving genetic gains in these breeding programmes.

Testing eucalypt durability

Before embarking on a very long-term breeding program for eucalypt durability, it is critically important that indirect tests for durability be validated. That is, durability gains using direct versus indirect methods must be compared. In the longer-term, this should be done in genetic tests. However, shorter-term assessments would also be valuable as described below.

Much of the work in the durable eucalypts focuses on early, indirect genetic selection for durability. This approach should be carefully evaluated because (1) it is unclear whether genetic improvement is necessary (i.e., does species durability exceed a minimum threshold?), (2) we do not know the levels of genetic gain that are possible because there is insufficient information on quantitative genetic parameters, (3) early, indirect selection has not been validated, (4) durability testing (direct or indirect) is time consuming and costly, and (5) selection for durability will decrease genetic gains in other traits.

The following experiment might be valuable for evaluating the questions outlined above. In native stands of *E. bosistoana*, harvest mature trees (15-30?) and then test durability from the top to the bottom of the tree. This experiment assumes that changes in wood durability from the top to bottom of the tree are analogous to changes over time at the base of the tree. Measurements should include (1) potential indirect measures of wood durability (e.g., extractive content), (2) number of rings of heartwood, and (3) direct measures of durability, including fungal tests and "graveyard" tests. The two primary uses of these data would be to (1) estimate correlations between indirect and direct measurements of durability at different stem ages and (2) estimate the upper limit of heritability. That is, estimates of trait variation between and within trees can be used to calculate repeatability, and as described by Dohm (2002), "When properly defined and measured, repeatability can set the upper limit to heritability." This general approach has been used in forest trees (Campbell 1965). By incorporating other reasonable assumptions, these data could be used to estimate direct and indirect gains in durability (e.g., relative gain efficiencies for indirect selection). Furthermore, base levels of durability could be used to decide whether genetic improvement in durability is even needed. Similar concepts could be applied to indirect tests of growth strain.

Direct assessments of eucalypt durability

Two 'direct' tests of wood durability were discussed at length: in-ground 'graveyard' tests and accelerated fungal cellar tests. Because Scion has been conducting graveyard tests of *E. bosistoana*, UC and Scion should collaborate more closely on future direct tests of eucalypt durability.

Indirect tests of eucalypt durability

Laurie Cookson (retired CSIRO Principal Research Scientist) spoke at a workshop on durable eucalypts (19-20 April; http://nzdfi.org.nz/news-and-events/resources/workshop-durable-eucalypts-protecting-and-enhancing-value/). Laurie has the experience to advise on the number of replicates required for fungal cellar testing to produce robust results.

Marco attended the NZDFI meeting (19-20 April), and noted that Tim Wardlaw (Forestry TAS) reported extractives in *E. nitens* (and possibly *E. globulus*) that were formed in response to wounding were quite different from normal heartwood extractives. Again, any indirect tests of durability should be validated before being applied in long-term breeding programs.

Lesley Francis (QLD timber pathologist) indicates that 2-year assessments of graveyard stakes from 19-year-old Gympie messmate (*E. cloeziana*; a durability class 1 species) showed more rapid decay in inner heartwood and intermediate heartwood compared to outer heartwood, even though all samples had similar extractives content. Within a sample zone, there were phenotypic differences in the severity of decay among samples, which may have a genetic basis. This work was initiated as part of the QLD Plantation Hardwood Research Fund (PHRF) projects about a decade ago, and a 10-year assessment of these stakes is planned for later this year. Lesley hopes to report results shortly thereafter. Lesley also noted that the Australian durability classification system is based on exposure of outer heartwood samples from mature/old trees. Many old growth eucalypt trees develop a hollow decayed pipe in their centre, indicating the lower durability of wood close to the pith compared to more mature wood in the same trees.

In summary, it is very unwise to base long-term breeding programs on indirect selection criteria that have not been fully validated, or design breeding programs without adequate knowledge of the relevant quantitative genetic parameters.

Products and processing infrastructure

The proposed strategy for using young trees for posts is not completely clear. If the current research programme is successful, there will be a market demand for young trees to be harvested early and used directly as round posts. Will small logs from these young trees be used directly as posts? If so, the non-durable sapwood will be in contact with the ground. Alternatively, will the sapwood be removed to produce posts of higher durability?

Over time, this problem will diminish as larger trees become available. That is, the sapwood will become a smaller percentage of the logs. Medium-sized logs may be peeled to provide high stiffness sapwood veneers, so that the heartwood peeler cores can be used as round posts. When larger logs become available, they may be sawn into square heartwood posts, with the sapwood being discarded or used for smaller specialty items.

These questions reinforce the point that it is very important to know the variability of wood properties within a tree. Not only is durability important (as discussed above), but also peelability and wood stiffness. Marketing studies and business plans should account for full utilization of whole logs of different ages and sizes.

7. Cypress

Cypress is unlikely to be one of the key forest systems in the future. The EAP had lengthy discussions about the cypress work, but did not achieve consensus. The upside is that the cypress work would help engage the farm forest community. Cypress is a priority for NZFFA members. This is their main area of interest and the rationale for their modest investment in the programme. To what extent should research on cypress be continued to retain the interest of these stakeholders? The downside is that the cypress work detracts from forest systems that are more likely to meet overall SWP goals. In any case, it is important to complete the ongoing cypress work, but the project should carefully consider whether cypress should be one of the focal forest systems going forward. The amount of effort devoted to cypress (i.e., versus other recommended activities) should be carefully considered at the upcoming workshop on cypresses to be held in October 2017. NZFFA should work more closely with Scion to reduce the costs of planting and maintaining cypress trials. SWP should investigate the potential of obtaining appropriate new grant funding to redress the funding shortfalls for the cypress research program. There is a need to quantify the funding shortfall to complete the proposed work program. Scion needs to clearly document what work can be delivered with the current program funding and then what activities cannot be delivered and cost out what extra funding would be needed to deliver these other activities. The latter is needed to realistically assess extra funding opportunities for NZFFA or other interested parties to work with Scion to source additional grant funding for this work.

8. Species/genotype site matching

The importance of the site/species matching cannot be overemphasized. This is important for selecting the most promising forest systems, and thus focusing the breeding programs and processing research on a small number of key species. This research should include modelling to identify potential suitable sites, but in the long-term, must also involve wide-scale empirical testing (experimental plantations). These plots and associated demonstration plantings will be invaluable for validating modelling results, promoting confidence among growers and processers, and for providing data for robust business plans.

9. Processing

Most of the issues associated with processing have been identified in the separate sections above. However, some additional questions relate to all species and all wood-based materials.

Species-level wood properties should be assessed throughout the R&D programme, not only for sawn timber, but also for glued wood products. Mechanical properties will need more testing once products have been selected. These include strength in bending, shear, tension, and compression, in all directions; fracture strength; embedment strength and fastener performance; stiffness; shrinkage; swelling; stability under changing moisture conditions; and fire properties, including flame spread and charring rate. A certain level of durability is also required for most building applications, even for "non-durable" species. Durability requirements and durability performance should be assessed for all likely markets, with and without surface-applied chemical treatments. Finally, processors may need answers to questions about sawing, peeling, drying, and gluing. Australian experience should be used to help answer these questions (for eucalypts), and North American experience should be investigated for Douglas-fir.

It will be extremely cost-effective to assess many of these wood properties with manufacturing of laboratory-scale product samples, for small scale testing, and market analysis, before moving on to full-scale manufacturing and testing of fewer selected products.

Drying work is being done as part of SWP, but needs to include high humidity drying schedules that have been successfully used at TAS and ACIAR (China). This includes their research on problematic species such as *E. nitens* and *E. dunnii*. Growth stresses need to be assessed and mitigation strategies need to be developed (i.e., depending on the particular product and market). For the thermal modification research, a feasibility study and business plan are needed to identify a viable market for the modified wood before making a decision to invest further, or abandon that line of research.

APPENDIX 1 – REFERENCES

The following references will be made available Marco Lausberg as a downloadable zip file.

Arnold, R.J., Xie, Y.J., Midgley, S.J., Luo, J.Z., and Chen, X.F. 2013. Emergence and rise of eucalypt veneer production in China. International Forestry Review 15(1):33-47.
China's plywood production grew rapidly over the past 15 years from around 9 M m^3yr^{-1} in the mid-1990s to over 55 M m^3yr^{-1} by 2011. Associated with this has been a proliferation of small-scale eucalypt veneer mills processing young (≤ 5 yrs) small diameter logs (mostly ≤ 12 cm small end diameter); by 2011 there were over 5000 such mills in China with a collective capacity to process well over 15.0 M m^3yr^{-1} of logs. We review key characteristics of this eucalypt veneer industry with special focus on three key regions for eucalypt veneer production in China. Factors that have spurred and facilitated the rapid growth of this industry are reviewed along with future challenges likely to emerge for China's eucalypt veneer industry.

Brown, A.G. and Beadle, C.L. (Editors). 2008. Plantation eucalypts for high-value timber: Enhancing investment through research and development. Rural Industries Research and Development Corporation Publication No 08/113, 182 pp.
This 'Plantation Eucalypts for High-Value Timber' conference proceedings addresses current challenges in developing a viable industry for plantation eucalypts to produce high-value timber. The focus is on the need for strong science to inform investors and reduce risk, and on areas where a lack of information may be impeding investment in high-value eucalypt sawlog plantations. These proceedings compile the presented papers and summarise the discussion forum. The papers span current research and investment issues along the whole value chain.

Campbell R. K., 1965. Phenotypic variation and repeatability of stem sinuosity in Douglas-fir. Northwest science, 39(2): 47-59.

Dohm M. R. 2002. Repeatability estimates do not always set an upper limit to heritability. Functional Ecology 16:273-280.
1. The concept of repeatability, the measurement of consistent individual differences, has become an increasingly important tool in evolutionary and ecological physiology. Significant repeatability facilitates the study of selection acting on natural populations and the concept has several practical implications for identifying traits. 2. When properly defined and measured, repeatability can set the upper limit to heritability. This is potentially a very useful interpretation of the repeatability of traits measured on natural populations because often, estimates of heritability cannot be obtained. Many recent reports of repeatability of individual differences for traits have made this interpretation. 3. However, repeatability estimates may not set an upper limit to heritability if: (a) measured traits are not genetically identical, (b) common environmental effects work in opposition to direct genetic effects, (c) the temporary environments for each trait are negatively correlated, (d) significant genotype–environment interaction is present, or (e) the traits are influenced by maternal effects. 4. The quantitative genetic theory that defines the concept of repeatability is reviewed and implications of violations of the five assumptions are discussed in the context of interpreting repeatability as an upper estimate to heritability.

Washusen, R. 2009. Improving the value chain for plantation-grown eucalypts in China, Vietnam and Australia: Sawing and Drying sub-project: Subproject 4. Processing sawn wood from thinned, unpruned 17-year old Eucalyptus dunnii from southern China.

CSIRO Client Report No. CMSE-2009-193, ACIAR GPO Box 1571, Canberra, Australia, 40 pp.
Two provenances of 17-year-old thinned, unpruned plantation grown Eucalyptus dunnii logs from Liuzhou, Guangxi Province, China were processed in a Chinese sawmill to produce dried appearance grade sawn wood suitable for manufacture of short length flooring. Sawing was conducted with a conventional back-sawing strategy with a single vertical band saw coupled with a reciprocating carriage. Boards were air-dried and kiln-dried in two matched batches and one batch given a steam reconditioning treatment. The aims were to determine: (i.) The inter-relationship between log end-splitting, the measured displacement associated with growth stress release (LGS displacement) and acoustic wave velocity (AWV) measured on standing trees, and important wood behaviour during processing, (ii.) The relationship between log external features and recovery, (iii.) Potential for improvement in processing and/or product quality with the application of a steam reconditioning treatment, and (iv.) Differences in product value and processing characteristics between two provenances of *E. dunnii*.

APPENDIX 2 – SURVEY OF PSG MEMBERS

On Tuesday April 4, 2017, the EAP met with the Programme Steering Group (PSG) to discuss initial impressions of the SWP programme. Attendees consisted of Glenn Howe, Andy Buchanan, and Kevin Harding (EAP members); Marco Lausberg (SWP); and the following members of the PSG: Peter Berg (Chair), Shaf van Bellekom, Russell Dale, Phil De La Mare (via phone), Angus Gordon, Bruce Manley, Graeme Manley, Alison Stewart. Absent members consisted of Russell Burton, Dave Hilliard, and Jez Weston.

The EAP distributed a list of questions to the PSG, to obtain written and verbal feedback. Key PSG feedback is summarized in Table X. The EAP developed these as key questions after reviewing the pre-meeting materials, attending the SWP progress update on April 3, and initial discussions among EAP members.

Table 1. Summary of written and verbal responses from the Programme Steering Group (PSG) to prompts by the Expert Advisory Panel (EAP). These topics were discussed on Tuesday April 4, 2017.

Question to the PSG	PSG responses		EAP comments
What are SWP strengths?	• Industry-wide collaboration • Forest product focused • Bet-hedging/synergism from multiple species	• Available background information • Multiple research providers	We agree. PSG strengths are roughly listed in our perceived order of importance.
What are SWP weaknesses?	• Wide 'focus' • Too many species/cultivars (e.g., eucalypts, cypress) • Overdesigned eucalypt programs (we do not need 'Ferraris') • Under-resourced in some areas • "Silos" lead to weak integration	• Weak translation between science and application • Business cases are missing • Unclear deployment plan • Little interest in new plantations • Redwoods not included	We mostly agree. PSG weaknesses are roughly listed in our perceived order of importance. We particularly agree that the programme should be more focused.
If you look at the entire forest system (planting to market), what is the weak link for Douglas-fir, non-durable eucalypts, and durable eucalypts?	**General weak links** • Dominance of radiata pine • Insufficient vertical integration of industry • Cost and availability of land • Dominance of steel and concrete • Building codes **Durable eucalyptus weak links** • Knowledge of durability • Time to delivery of planting materials • Lack of critical mass • Genetic selection and pests	**Douglas-fir weak links** • Rotation age, form, SNC • Processing and markets • Wildings • Site matching **Eucalyptus weak links** • Wood quality and markets • Site matching • Pests **Cypress weak links** • Lack of critical mass	We agree. For each species, PSG weaknesses are roughly listed in our perceived order of importance. We particularly agree with comments that address issues associated with integrating the entire forest system.
Who is going to plant each of these resources?	• **Eucalyptus** – Sustainability strategies for some companies	• **Boutique species** – Farm foresters • Carbon farmers	
How does one integrate long-term strategies into a shorter-term grant program?	• We received no written comments on this topic, and our discussions did not lead to any concrete recommendations.		This topic should be addressed by the SWP programme. This will be particularly important for (1) validation of species/site matching and (2) validation of eucalyptus durability.

APPENDIX 4 – UOC/MRC RESPONSE

UC/MRC NZDFI comments
To SWP EAP draft report dated 5th May 2017

Clemens Altaner and Paul Millen

9th June 2017

I. Introduction

The EAP report introduces the 'forestry system' as the basis to describe a forestry value chain from seed to forest to processing products to markets. Comment is made of the need to focus research on weak links in the forestry systems. NZDFI has a strategic focus to establish a durable hardwood 'forestry system' in New Zealand dryland regions. We agree that there are opportunities for focusing research on processing to test and demonstrate how 'fit for purpose' products can be made from durable eucalypts. However, we note that market research is outside the scope of MBIE partnership funding and FGLT funding. This needs to be undertaken by the SWP industry supporters.

II. 1. Our comments on EAP Strategic Recommendations

1. NZDFI agree that there is a need to focus on a smaller number of key forest systems.
2. We note that durable eucalyptus for vineyard posts is described as a key forest system. However, there is significant potential for the export of durable posts and poles as well as sawn products such as decking, cross arms and sleepers. Also the potential to peel for manufacture of very high stiffness LVL.
3. The focus of our tree breeding programme is on three principal species. We do not support this being reduced to one species as this will constrain the potential for planting new forests as no one species is adapted to grow across the wide range of site types within NZ dry east coast regions. We have consulted our industry supporters on this and they agree with the number and the selection of species in our programme.
4. We agree with the summary of what is required to give growers confidence. We have been working toward this from when the NZDFI was first established in 2008. However, a medium term commitment was made to first fund our tree breeding programme and our trials to learn about site species matching as well as PSPs for growth model development.
5. It is too early to develop a brochure to promote the use of NZ grown durable eucalypt hard wood. NZDFI has already produced two brochures previously on growing durable eucalypts and has an extensive web site that offers a significant amount of information. We have already commented that we understand that this type of marketing expenditure is outside the scope of the SWP programme.
6. Agreed.
7. It is difficult to develop a robust business case without growth models. Given the NZDFI research programme only started in 2008 we have limited PSP data for developing traditional

empirical growth models. Therefore we are working on developing physiological models to predict growth. These models also require the development of a stem taper volume function for predicting heartwood growth and to complete a biomass assessment for predicting carbon sequestration. Insufficient funding via SWP programme requires that funding for this research needs to be sought outside of the SWP partnership. Therefore an application is planned to be made to Ministry Primary Industries (MPI) next Sustainable Farming Fund (SFF) round later this year.

8. Agreed.
9. We support work on continuing product development of high stiffness products for Douglas fir and non-durable eucalypts. However, we note that successful peeling of non-durable eucalypts for LVL will be constrained by growth strain. We comment further later in section 5 on page 4.
10. We understand that site species matching research is required. Our earlier SFF projects funded planting a large number of trials in different locations so as to work on this. These have started to yield valuable data since 2014 when we got a second AGMARDT grant to work on this and then more recently there has been some SWP support. However, much more research is required and this is planned to be part of the SFF application being made later this year.
11. NZDFI has always been committed to outreach and has a wide 'community of interest/stakeholders. This has been achieved through the extension programme run as part of the two successful SFF projects that were delivered from 2010 to 2016 and the current UC SFF project that NZDFI is actively supporting. There is scope for more outreach under SWP programme, however, additional funding would need to be allocated to do this. There are also a number of commercial scale plantings of durable eucalypts in Marlborough and other east coast regions that have been planted in the last six years. However, we have been deliberately constrained encouraging planting of large blocks of durable eucalypts until we are confident about site species matching and that we can offer improved seed or cuttings.
12. We consider that there is a significant challenge for the SWP to increase industry participation/collaboration given the wide diversity of species and broad geographic spread of the parties that are involved. We have been collaborating with JNL since 2010 as they host a large number of our trials and we value their support for SWP.
13. We agree that MBIE need to be engaged in the SWP programme.
14. We agree that seeking new funding from Australia is worth investigating. However, this may have limited scope as the only SWP species that is significantly planted in Australia is *E. nitens.* So any collaboration would best be requested on a project by project basis rather than requesting broad 'all of SWP' support.
15. We consider that increasing collaboration between SCION and UC is limited particularly due to the Project Steering Group not prioritising the preparation of an overall strategy for the SWP programme.

II. 2. Our comments on Project specific recommendations

1. No comment.
2. (1) Refer to our comments about site species matching research funding under paragraph 10 above.

(2) We are investigating the option of an Australian expert testing our cores in a fungal mass-loss test.
(3) We will give consideration to establishing economic weights for our selections once we have sufficient data for our trials to be able to understand the genetic architecture we have captured within our breeding populations. We plan to prioritise updating the business case for durable eucalypts over the establishment of economic breeding values. As we are working with a wild population we think we can make good progress by removing unacceptable material (e.g. form). When considering future breeding cycle's economic prioritisation becomes more important.

3. No comment.
4. No comment.
5. It has already been agreed that a single SFF application for site species matching research of all SWP species cannot be made due to the limitation of on the level of funding that can be applied for from MPI. This is a total of $200,000 per annum for any new project with a maximum of three years. There is also a requirement that a SFF project has a strong community of interest and additional industry financial support that is independent of the SWP programme. Hence, given NZDFI's success with SFF projects previously, and that we have industry support for NZDFI outside of SWP, we consider we have a greater likelihood of success with a separate SFF application. It will also be much simpler and lower cost to manage.

III. Our comments on parts of the Project Evaluation section

1. Project organization and management

No comment.

2. SWP strategy

Forest resource

Empirical site-species matching requires significant resources to establish more trials. NZDFI is planning to seek additional funding for a SFF project that will include planting new trials in localities that will widen the scope of our research. (see II 2.5 above).

Processing infrastructure

From a NZDFI perspective the most significant processing we plan is to undertake a peeling trial of young small diameter logs of our durable species. This will be with logs from 14-15 year old trees.

This can be undertaken using JNLs plywood lathe. After assessing recoveries and veneer quality the veneer would be available for a LVL gluing trials, a reoccurring processing issue. The manufactured LVL would then be available to test material performance. This work will involve UC's timber engineering group (led by Dr. Minghao Li).

Products and markets

We have already commented in the introduction that market research is outside the scope of MBIE partnership funding and FGLT funding. This needs to be undertaken by the SWP industry supporters.

However, we have previously undertaken research of products and markets for durable hardwood. Vineyard Timbers has over 1,000 sawn NZ grown durable hardwood posts in vineyards in Marlborough. Marlborough Lines have established that there is international demand for cross arms.

The average cubic metre value of exotic hardwood timber imports are 300% greater than the export value of NZ sawn pine. Products and markets are not the weak link in our durable hardwood forestry system rather market demand and prices is what has driven the purpose for establishing NZDFI tree breeding programme.

NZDFI's research programme is committed to ensuring that hardwood grown in durable eucalypt forests has properties that ensures processing is efficient and that products are 'fit for purpose' in the market. This includes researching the possibility of *E. bosistoana* being used to produce high stiffness LVL of 16+ GPa. We already know from our SFF project that NZ grown *E. globoidea* produced on average 14 GPa veneer.

Business plan

We support there being a focus within SWP on developing products for international markets. We have established there are high international values currently being paid for durable hardwood.

Therefore, despite our interest in supplying vineyard posts for domestic markets, our vision is for NZ to establish a hardwood industry that generates substantial new wood exports.

If our SFF application is successful, one of the outcomes from this project is that we have a larger amount of data from our PSP trials, along with completing a taper function and biomass study that can be used to produce a short rotation post/pole growth model for our species, whether for vineyards or peeling for LVL. This model will then be used to undertake an economic analysis across a range of sites with low, medium and high productivity. In addition, longer rotations could be modelled using physiological parameters so that a business case for a sawlog regime can be completed.

3. Outreach

Please note our comments on strategic recommendation II.1.11 above.

4. Douglas fir

No comment.

5. Non-durable eucalypts

We note that the EAP highlight the need to segregate quality logs from the existing *E. nitens* resource. The (or a) major factor is growth-stresses in these trees that can cause significant end splitting (this was also highlighted by JNL's *E. fastigata* peeling trial). We are exploring technology to do this but this is a long way from a working tool. Scion has NIR expertise and tools which could help with this.

We recommend that breeding to reduce growth-stresses needs to be included in the targeted traits. We have developed the 'splitting test' which is a straight forward low cost method and reasonably quick (2 years) method that could be used to screen the existing *E. fastigata* and *E. nitens* breeding populations for growth-strain and then rogue the orchards.

We would support a workshop on solid wood products and the processing challenges from plantation grown eucalypts. Much can be learnt from overseas (Australia, South America, South Africa) experience processing eucalypts. SWP and NZDFI have successfully used this format to peer-review their research plans in other areas.

6. Durable eucalypts

Breeding programmes

We plan to review what we have learned about the various genetic traits of interest and rank these in order of priority. Then we can increase our selection intensity for deployment in seed orchards.

Durability

We are confident that it is of strategic importance to include durability in genetic selection at an early age, i.e. to improve corewood. This is based on:

1) preliminary data showing that samples from (only two) NZ-grown *E. bosistoana* trees, although still considered durable, were decaying quicker than a tropical timber of known high durability (termite resistance, however, seemed to be excellent).
2) The fact that early rapid growth in forestry plantations encourages the production of corewood, which is known to be less durable than outerwood.
3) reports showing large variation in the durability between individuals of a species grown in NZ plantations (e.g. *E. globoidea*) (Page et al., 1997).
4) reports that within eight year old trees of a durable eucalypt species (i.e. *E. cladocalyx*) there are individuals with very durable corewood (Bush et al., 2011).
5) market research revealing that high value industrial grade timber such as cross arms will secure a premium if the durability can be certified that it will provide an extended service life.

We do not consider that selecting for durability using a direct decay assessment is as critical as the EAP makes a case for. EAP/SWP members have suggested that lab-based tests are not the best measure as they only assess the resistance against the one tested thread. But there are multiple threads each (insects, fungi, termites, marine borers) requiring an individual assessment. A better way would be a grave-yard field test. But these are very time consuming running for years/decades and also need to be repeated in different environments.

On the other hand it is known that the main factor that contributes to natural durability is heartwood extractives. Extractives content in the heartwood is highly variable (e.g. 10-fold in 4 year old *E. bosistoana*). One could argue that selecting for high extractives content could be a single measure to increase the probability of resistance to all forms of biodegradation. As extractives content can also be measured quickly we are able to increase the selection intensity. The objective of selecting for high extractives content is to rogue the breeding population of the lower tail which is causing the majority of the wood quality problem.

At a later stage we will confirm durability of selected trees with high extractive content according to standards. This will reduce the number of samples and therefore required resources. It is worth noting that different standards apply for different export markets. Furthermore, these accreditation tests require larger samples which are not available at this stage from our breeding population, implying a delay in the supply of improved planting material.

However, we do agree that it is helpful to ascertain the correlation between decay and extractive content. We have the opportunity to work with Dr Laurie Cookson, who has already developed a testing protocol for mass loss using our heartwood cores which we analysed for extractive content. We will include this in a work plan under next year's SWP funding. We can review our selection strategy for heartwood quality based on these results.

We are also aware that there are variations in the relative composition of the heartwood extracts. As part of the SWP funded work we are currently developing analytical tools to measure these. Among the trees with high extractive content we will then be able to select those with the most potent extracts.

We agree that we do not know the quantitative genetic parameters for quantity and quality of heartwood. We are confident that we will obtain the critical information from the assessments of our breeding trials.

We see major logistic challenges to get permission to fell 15-30 mature native trees. Some species in the NZDFI programme are rare (endangered) in Australia. We expect high costs for such work as it would involve major forest harvesting and wood processing in Australia. There are a very small number of known mature stands of *E. bosistoana* in NZ, all of which are in Northland. While it may be possible to obtain access and consent of the landowners to fell a number of trees, we are not confident that this approach would be more cost effective or provide better information than screening our breeding populations. Furthermore we have some practical reservations:

- identifying tree age in eucalypts is known to be challenging and we have already found that annual rings are not pronounced in *E. bosistoana*.
- we are uncertain on how Dohm (2002) accounts for an overriding axial gradient, which makes comparing tops of old and bases of young trees difficult.

Products & processing

'Peelability' and stiffness are mentioned as key properties. As mentioned above (II.1.9 / III.5) we would add growth-strain if it is not included in 'peelability'. We are working on the details/logistics of a peeling trial for durable eucalypts (III.2) as well as a sawing trial of 15 year old trees to produce sawn timber for graveyard trial stakes and vineyard posts. This is being planned to be part of our future SWP funded work. High stiffness (and low growth-strain) will be selected for by 2019 for all NZDFI durable eucalypt species except *E. globoidea* under our current SFF project. It would be possible to assess those traits in the existing *E. globoidea* breeding populations, however, this will entail significant cost and is outside the current scope of our SWP programme.

7. Cypresses

No comment.

8. Species/genotype site matching

We agree this important and will be a part of our ongoing research programme.

9. Processing

Durable eucalypts could have an advantage in fire properties. Fire properties are critical for timber building designs. This could be an area of research involving the UC timber engineering group (Dr Minghao Li). Fastener performance could be another.

References

Bush, D., McCarthy, K., and Meder, R. (2011). Genetic variation of natural durability traits in *Eucalyptus cladocalyx* (sugar gum). *Annals of Forest Science* **68**, 1057-1066.

Page, D., Foster, J. B., and Hedley, M. (1997). What's new in Forest Research. Vol. 245, pp. 4. New Zealand Forest Research Institute, Rotorua (NZ).

Dohm M. R. 2002. Repeatability estimates do not always set an upper limit to heritability. Functional Ecology 16:273-280.

EAP Clarifications and comments on UC feedback

1. The development of breeding programs for three species will obviously constrain progress in any one species. However, the stakeholders seem to agree with this extensive approach, recognizing that a diversity of species/site matching options is a priority for them.

2. The site/species matching and evaluation is critical, and more typically precedes the development of focused breeding programs.

3. Because we are well into the SWP project, it is not too early to begin planning and developing SWP-specific outreach publications because these will assist in identifying knowledge gaps that need to be addressed.

4. Yes, robust business plans require good growth models, hence the high importance of the species/site matching. The development of physiological models makes sense in the short-run, but it is also important to develop new PSP data for longer-term validation.

5. Anytime a breeder makes genetic selections, they are implicitly applying economic weights. We recommend that this be done explicitly, as compared to implicitly (see clarifications to the EAP report). Although the UC response focuses on tree form, growth strain, and durability, we also heard a very long list of potential selection criteria at our meeting in Christchurch. Using explicit economic weights is important because, as additional traits are added to a breeding program, this will reduce the gain in valuable traits.

6. For the non-durable eucalypts, the focus on improving growth stresses and the development of a splitting test make sense. We look forward to seeing quantitative genetic information on this trait, and ultimately, the genetic correlation between this indirect selection criterion and the target trait (e.g., improved drying and processing performance resulting in increased value of sawn products).

7. For the durable eucalypts, the plan to rank the genetic traits is a good one, but we also recommend that a quantitative value also be assigned. This will help to decide where the threshold cut-off should be for including or excluding traits.

8. The UC response states, “We are confident that it is of strategic importance to include durability in genetic selection…” However, this conclusion seems to rely on phenotypic data, but it is the genetics of the trait in your target species that should drive this decision. While selection for durability may be important, it all depends on the potential genetic gains, the value of this genetic gain, the costs of achieving this genetic gain, and the impacts on other key traits like stem form. Certainly, the genetics of durability should be examined, but again, we caution against designing a very long-term breeding program on untested assumptions.

9. We continue to believe it is critical to compare indirect tests of durability to the direct target trait. Even if positive genetic correlations exist, these correlations will need to be very high to be useful in breeding programs. If these tests do not achieve high correlations, then their use in a breeding program could be disadvantageous. In short, it is unwise to design long-term, expensive breeding programs without validating these approaches along the way. We’ve seen many indirect selection criteria (particularly for wood properties) proposed, used, and tested, and only a very few have ultimately been adopted as standard practice.

APPENDIX 5 – SCION RESPONSES

Comments on EAP review - Scion June 2017

The EAP comments were all thoughtful and helpful in the context of the wider programme.

Genetics

A couple of comments that relate to the timing/biology of the existing breeding populations are below for consideration.

Currently there are 3 non-durable eucalypts- *E. regnans*, *E. nitens* and *E. fastigata*. Suggest that *E. regnans* is lowest priority and could be removed from the programme, but loss of *E. fastigata* would be disappointing. *E. nitens* is a key eucalypt for colder areas, whereas *E. fastigata* is a key eucalypt for warmer areas and has perhaps the highest potential for increasing plantation area.

E. regnans and *E. fastigata* breeding populations need to be turned over as they are getting too large and need thinning. They need to be measured, analysed, selections made and the next generation seed collected for sowing. It would be good to achieve this during 2017-18 otherwise we risk the investment put into these trials.

Economic weights are very useful for defining selection criteria for end products and link directly with market. Studies to undertake this research is a lot of work and expensive and needs to be fully considered before SWP goes down this path. In addition, weights are determined by current product(s) that perhaps don't exist and maybe that they lose relevance even within the timeframe of this programme. Suggest industry input before final decision is made.

Suggest the cypress trials are established, but the *C. macrocarpa* breeding population is not sown. We will pursue this with smaller growers via SFF or another funding source. Most of the existing work that has been started can be undertaken in 2017-18.

Some of the comments on the Douglas-fir programme need some comment.

- NZ is a different environment to the USA so the high elevation/low elevation is not as relevant as the colder/warmer/exposed classifications that are more relevant in NZ. The approach is still relevant and could be considered. Noting this is not breeding, but site/species matching so could be addressed in the site/species matching research area?
- Improvement targets for Douglas-fir have already been set during the SWP Douglas-fir breeding seminar.
- Research and industry knowledge in NZ has shown that wood stiffness can be an issue on colder sites, so we believe that it is important to retain this as a breeding trait.

- There is some discussion that SNC in Oregon/Washington may not be SNC alone. Because of the heritabilities and the importance of forest health to NZ growers we still believe that SNC/health is important to pursue. This may be, as suggested, as crown health or needle retention.

The Scion Strategic Science Initiative Funding (equivalent to the Core funding) is tagged to the breeding programmes of the Scion SWP species for genomics research but is not species specific.

Processing

The research we (processing) have done has strongly been done with industry direction i.e.

- Find a use for Douglas fir thinning's material, hence the OEL trial in year one
- Likewise find a new use for Niten's material, hence the OEL trial in year two
- Attempting to solve the drying issues for Niten's and Eucalypts in general hence our primary SWP focus on drying backed up with several literature reviews.

The SWP is strongly led by the forest growing industry sector, we have little industry processing leadership, we certainly could do with more. However it needs to be noted that the closer you are to the market the harder it is run a cooperative research program, as the industry is looking for a market position they can secure on their own.

In terms of new uses for Douglas fir Scion and the industry have done extensive processing trials mainly around structural timber recoveries. The industry themselves could easily do LVL and CLT trials, I know Xlam have made CLT with Douglas fir. There nothing stopping any LVL manufacturer from undertaking Douglas fir LVL trials. We struggle to see the new SWP science in applying Douglas fir to LVL and CLT products, if anything these would be simple grade recovery followed by assessment of properties projects

We have already proposed the following projects which I believe address some of the issues raised

- Visits and information gathering to Australian hardwood processors to collect information (information not in literature but from operators) on hardwood drying and gluing
- LVL trials with JNL hopefully following the project above

I agree we could look at the mechanical properties of other Eucalypt species. However I believe first we need to reduce the processing drying losses which is a key factor in the processing viability question before we invest in new mechanical property testing (there is historic mechanical properties information which can be used to help with a species choice).

It would be really good to see if the SWP overview research document could be finalised once the SWP direction is finalised and used to help get more shareholders/clients.

EAP Clarifications and comments on Scion feedback

1. **Role of *Eucalyptus regnans* and *E. nitens*.** We agree that SWP should consider removing *E. regnans* from the programme to allow more effort to be devoted to higher priority activities. We understand the potential roles of *E. nitens* and *E. fastigata*. Again, these considerations highlight the need for a good long-term strategy for species/genotype site matching that can ultimately contribute to the wise development of the most promising forest systems in the long-term.
2. **Economic weights.** The development of economic weights need not be expensive, although it can be. For example, they can be based on expert opinion. Processers usually have a good sense, if not hard data, on what characteristics of the log resource negatively impact its processing, and what qualities are desirable for ideal recovery, ease of processing, and production of high quality products. In deciding which traits to include in a breeding program, it is very important to have some idea of the relative economic impact of alternative traits. Typically, most of the breeding emphasis should be on growth and adaptability traits. Except for occasional threshold traits, wood properties often have relatively low genetic variation (so gains are small) and impacts on products can often be addressed very effectively via processing. For example, wood stiffness can be improved by breeding, but sufficient within-tree wood variation in stiffness properties may exist to allow sawn or veneer products to be sorted using in-line segregation tools. This could immediately produce engineered wood products with desired wood stiffness properties allowing long term breeding to produce higher stiffness trees, if this is a priority for the species.
3. **Douglas-fir breeding zones.** In the report, "elevation" was used as a surrogate for factors that result in colder, warmer, and exposed sites. Yes, we agree that this topic is an important aspect of the larger SWP species/genotype matching research.
4. **Wood stiffness.** We recommend putting little selection emphasis on wood stiffness, although it should be monitored. That is, the extent of selection might be to remove genotypes that fall below an acceptable threshold. This threshold should be set in consultation with industry processors and the Scion processing research group who will be able to propose a critical value at which product quality/value is compromised. Increases in growth will be very important to compete with radiata pine, and many of the Douglas-fir materials in operational NZ plantations and genetic tests have substantial problems with stem form, which has a much greater impact on product value than does wood stiffness. Furthermore, tolerance of SNC needs to be considered. Breeding progress for each of these very important traits will be reduced by selection for wood stiffness.
5. **Processing and market position.** A critical mass is needed to develop a new, economically viable forest system. Thus, cooperative efforts benefit everyone, and seeking "market position' at this early stage is not desirable for any of the players. This point should be emphasized to the "growing industry sector."
6. **Processing in general.** We agree with all the processing related comments. Many of our processing related recommendations in the report involve looking toward the future—the current research is a good start but insufficient for the long-term. In terms of processing leadership, is there any prospect of more staff in this area (e.g., supported by Scion's CORE funding)? Industry needs to know what works and what doesn't work (at a small scale) before they commit to expensive full-scale trials. Manufacturers will be more likely to do full-scale trials if they have the results of small scale manufacturing and testing that shows what technical improvements are possible (e.g., in strength, stiffness, durability, etc).