New woody crops and industries for the wheat belt of southern Australia

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Introduction

Over the past decade Australian R&D agencies have screened the native flora for candidates for domestication to create new woody crops. Modifying agriculture to incorporate woody crops is one strand of national R&D aiming to develop treatments for dryland salinity in the low rainfall (300-650 mm rainfall per year) wheat/sheep regions of southern Australia. The native flora is the preferred source for woody crop species (in contrast to introduced species) because they are adapted to local conditions, present less risk of becoming weeds and there is a very diverse flora from which to choose.

The search of the native flora was stimulated by earlier promising results achieved with commercial development of mallee eucalypts in Western Australia (Bartle et al 2007). Mallees are a prominent group in the Australian flora and had a prior history of use for production of eucalyptus oil from native stands. They show promise as an Australian analogue for willow and poplar that are used as short rotation coppice species in cooler temperate climates in the northern hemisphere (Dickmann 2006).

Experience with mallee posed the obvious question: are there other native species that could be readily domesticated and become commercially attractive crops? This question was addressed in the Search and FloraSearch Projects (Olsen et al 2003, Bennell et al 2007, Hobbs et al 2007). These projects followed a systematic process to screen the ~10,000 species in the native flora in each of the south west and south eastern regions. This paper provides an overview of this work and progress towards establishing industries based on the new woody crops.

Screening process method

The process first specified appropriate product targets to guide species selection and then progressively eliminated uncompetitive species based on assessment of biological and product potentials at increasing levels of resolution and cost. The following steps taken were:

1. Initial assessment of potential products: Selected products had large markets and potential to add value to biomass by regional processing. They included processed wood (e.g. paper, panel board, charcoal), extractive chemicals, fodder and bioenergy.
2. Initial assessment of species: Existing generic level information on species attributes (taxonomy, morphology, ecology, plant form and size, diversity, geographic range) were assessed from the literature and expert knowledge, narrowing selection to a few hundred in each region.
3. Coarse testing: Species selected in step 2 were subject to low cost assessments such as wood colour and density to indicate suitability for products selected in step 1.
4. Detailed assessment of plant biology: Species from step 3 were subject to more intensive collection and analysis of plant data, and detailed assessment of characters such as weed risk, tolerances to environmental stresses, ease of propagation, quantity and quality of yield and production systems. Steps 3 and 4 reduced selected species to about 50 in each region.
5. Detailed testing for products: Remaining species were subject to progressively more intensive laboratory testing of their suitability for products, until a final select group were subject to sample product manufacture and evaluation.

Table 1 shows the selection process for the south western region down to step 4. With sample test results from step 5 each of the south west and south east regions identified ~20 species that showed promise for one or more products by achieving product test results comparable to current commercial species. A short list of species was selected for more intensive development. These included a selection of mallee and woodland eucalypts, some *Acacia* species and the fodder shrub, *Atriplex nummularia*.

Table 1 Progressive selection of species for domestication potential in the south west region

Total number of native species in Western Australia (WA).		9977
Eliminate species listed as rare (likely to lack adaptability for use as crops)		7965
Eliminate monocotyledons (selects for woody species)		6339
Species that occur in at least one of the 4 botanical regions of the wheat/sheep zone		3664
Species taller than 4m (available height data used as a surrogate for growth potential)		484
Species taller than 4m distributed across the four wheat/sheep botanical zones	Avon wheatbelt	309
	Esperance sandplain	266
	Geraldton sandplain	219
	Mallee	293
Species taller than 4m occurring in all 4 botanical regions		68

Product selection method

Target products were selected so that potential new supply was credible in relation to potential market demand. Recent estimates indicate that with appropriate planting design woody crops could make a sufficient contribution to salinity control when occupying <10% of farmland (Cooper et al 2005). Even this small proportion of planting could generate 40 million dry tonnes biomass per year, comparable in size to the national grain crop (Bartle et al 2007). Target products were therefore those that might use biomass on a bulk commodity scale. For prospective market sectors see Table 2.

Table 2 Product options for woody crops (from Olsen *et al.*, 2004)

Product category	Product subcategory	Examples of particular products
Wood products	Panel board	Particleboard, medium density fibreboard, composites
	Processed wood	Pulp, paper, biomaterials, charcoal, activated carbon
Bioenergy	Solid fuel	Electricity, industrial heat, firewood, wood pellets
	Liquid fuel	Alcohols, bio-oil, Fischer-Tropsch liquids
Industrial products	Chemicals by conversion	Pyrolytic and gasification products
	Extracted chemicals	Oils, solvents, tannins, gums, resins
Forage and fodder	Direct grazing	Woody forage
	Manufactured fodder	Feed pellets
Sequestered carbon	Below ground biomass of harvested woody crops	

With the exception of forage grazing there are no current industries using woody crops for any of these products on any scale. Therefore to achieve scale and diversity in woody crop industries not only will it be necessary to create new woody crops, but it will also be necessary to create new processing industries.

Bulk biomass supply for new processing industries will use all above-ground parts of the woody crop and consist of about equal parts of wood, leaf and bark/twig. The new industries could be designed to produce complementary products that make use of all biomass components. For example, an industry now being developed in WA, plans to use whole mallee biomass in an integrated process to produce activated carbon (from wood fraction), eucalyptus oil (leaf) and electricity (residue) (Enecon 2001).

Agronomy and production systems

The short-listed species identified in the Search and FloraSearch Projects are being inducted into agronomic development. Plant taxonomic work has been undertaken to clarify species boundaries for germplasm collection and progeny testing as the foundation for genetic improvement programs. Field establishment and on-going crop management practices are being evaluated.

Perhaps the major challenge is to efficiently integrate woody crops into the existing wheat/sheep agricultural system. Woody crops are unlikely to be able to displace conventional annual crops and pastures on economic merit alone. But as a complementary component of a new more complex system, woody crops may deliver in aggregate enough economic, environmental and social benefit to constitute a major advance in wheat/sheep zone agriculture.

In many areas of the wheat/sheep zone salinity control will be an important motivation for woody crop development. Salinity is driven by the under-utilisation of rainfall by annual crops and pastures, surplus water is able to percolate below the depth of the root zone, where it can recharge groundwater systems and mobilise salt stored in subsoils. The thesis is that deep-rooted, perennial woody crops could complement annuals by capturing and consuming a proportion of their water surplus. An essential condition of complementarity is that the woody crop gains more than its areal share of water. This expansion of the woody crop hydrological footprint, while retaining the option for integration with extensive annual cropping, could be achieved in two conceptual planting systems:

- spatial arrays of belts or small blocks designed to passively intercept lateral flows of surface or shallow sub-surface of water, and when the techniques are developed, to receive water actively harvested and transferred from adjacent areas not suited to woody crop planting.
- temporal cycles of woody crops alternating with annuals (phase cropping). The woody crop phase dewaters the soil profile which is then replenished slowly during the following annual crop phase.

The case for belt systems has been considerably enhanced by recent research. This research has focused on mallee but results should be broadly applicable to woodland eucalypts on suitable sites across the wheat/sheep zone of southern Australia. It shows:

- where extra water is available mallee has exceptional transpiration capacity, i.e. several times rainfall. This is reflected in enhanced yield. Mallee also has great plasticity in being able to reduce water use to tolerate drought and respond rapidly when rain comes (CRC Salinity).
- on conducive soils mallee belts create zones of extensive vertical (>10m) and horizontal (up to 20m) depletion of available soil water thereby allowing a narrow belt to create a substantial soil water sink (Robinson et al 2006, Sudmeyer and Goodreid 2007). Data is being collected to account for the negative impact of lateral root competition on adjacent crops (DEC & DAFWA).
- mallee growth is primarily controlled by soil profile characteristics and local water availability. Figure 1 shows that these local site factors can over-ride rainfall in their impact on mallee growth. Recent growth data shows that full site occupancy and growth by mallee can be achieved at relatively low planting densities (<1500 stems/ha within the belt area).

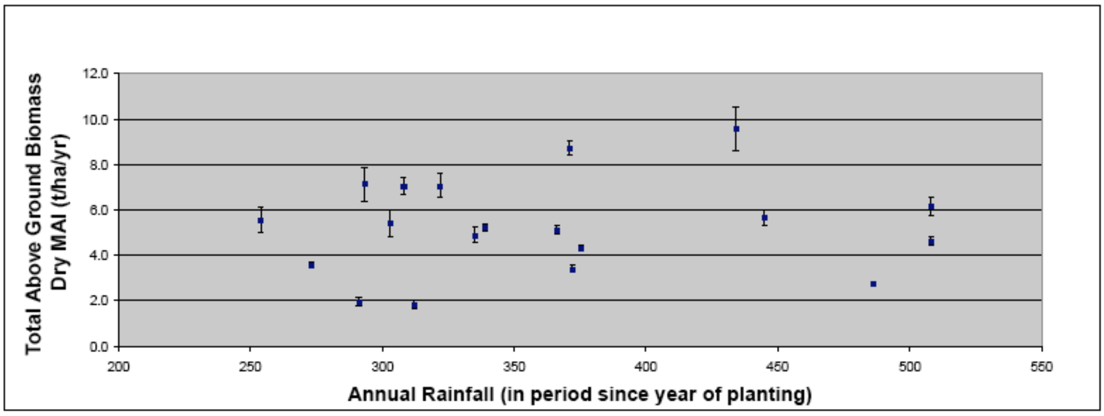

Figure 1 Relationship between mallee yield and rainfall in the wheat/sheep zone in WA

The water sink generating potential of woody crops, and the opportunity to deploy them on suitable site types in narrow belts designed for passive and active water harvest, looks promising for both salinity management and biomass yield. However, many variables influence the amount and potential capture of run-off. These must be better understood to guide design of efficient systems.

Farm economics and industry feasibility

There are now sufficient empirical data on mallee production costs and performance taken from extensive belt planting in WA to do preliminary economic analysis, and to undertake assessment of the likely feasibility of industry development projects from the biomass supply perspective. The Imagine model (a paddock scale discounted cash flow analysis) has been used to investigate the comparative economics of woody crops and conventional wheat/sheep enterprises in the WA wheatbelt.

At the farm level the premise is that large scale adoption will not occur unless the woody crop can at least break-even with conventional enterprises. Current best practice for 2 row mallee belts (establishment costs $1300; yield 7 dry tonnes/ha/year; biomass selling price of $39/green tonne; competition effects on adjacent annual crops accounted for) generates an equivalent annual return (EAR) of -$47/ha compared to conventional enterprises >$60/ha. There are several opportunities to reduce costs and increase revenue that could eliminate this shortfall, including:

- Increase yield by better site selection, layout and applying active water harvest practice. These could increase yield to 9 dry tonnes/ha/yr and reduce the EAR shortfall by >$20.
- Reduce costs by adopting a single row rather than 2 row belt, thereby halving planting density and reducing operational costs. This improvement, along with better yield, could lift EAR onto the positive side of the ledger.
- Rising global and national concern about climate change appears likely to generate a strong price for sequestered carbon. For harvested woody crops most sequestration will occur in root systems. Well managed stands are expected to have an annual root biomass increment of 1 to 2 tonnes of carbon dioxide equivalent (CO_2e) per km of belt. Combined with preceding options for reducing costs, an attractive carbon price could help mallee crops achieve comparable EAR to conventional crops and pastures.
- Climate change management strategies should also drive a strengthening of markets for bioenergy. As a renewable fuel, biomass will not be subject to emissions controls and this will help it compete with fossil fuels. This may be reflected in a stronger relative price for woody crop biomass than was used in the analysis above.

The Future Farm Industries CRC will conduct analysis to demonstrate whether these advances can lead to supply of bulk woody biomass under terms that make new processing industries feasible.

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