

A review of Short Rotation Crops (SRC) environmental and economic externalities - Australasian implications

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1. ABSTRACT

A review of Short Rotation Crops environmental and economic externalities has shown that SRC can provide a multitude of benefits to the environment and economy en-route to bioenergy production. New Zealand and Australia have opportunities to capture many of these benefits. In the case of New Zealand, the strongest case can be made for using eucalypts in a wastewater context where the crop is designed as a nutrient stripper. However successful bioenergy conversion is not implemented to date, although forest processing residues are providing renewable bioenergy to the forestry sector. When a bioenergy market emerges, it will bring the investment and infrastructure of a bioenergy fuel market, providing an avenue for SRC utilisation.

Australia on the other hand has a very different scenario. The synergy of salinity mitigation, mallee eucalypts established for eucalypt oil production and conversion through the Integrated Mallee Processing plant at Narrogin in Western Australia producing activated charcoal and electricity have initiated a potential viable land use option. Based on this first plant, more plants are likely to be developed.

2. INTRODUCTION

The vision of the IEA Bioenergy strategic plan for 2003–2006 is: “ To accelerate the use of environmentally sound and cost-competitive bioenergy on a sustainable basis, to provide increased security of supply and a substantial contribution to future energy needs (IEA 2002).

As global recognition of the need for renewable energy increases, the opportunity for bioenergy from short rotation crops to make a significant contribution to energy production is often debated. It is apparent that SRC is a marginal economic proposition in many countries as a stand-alone crop. To be economically viable, the crop must meet other land use needs while providing a bioenergy source.

Task 30 has initiated a review of the environmental and economic externalities of SRC to develop a better understanding of the implications for broadscale uptake and bioenergy production. While the review has concentrated on the *Eucalyptus* genus reflecting the geographical and national forestry interest of the authors (Ian Nicholas-New Zealand; Don McGuire-Australia and Laercio Couto-Brazil), many similarities exist with northern hemisphere SRC as well (Nicholas *et al.*, 2003 in prep). This paper summarises much of the information in this review, with a particular emphasis on implications for New Zealand and Australia on the role of SRC in providing a long-term sustainable land use. The review also recognises that other factors impact on the management and role of SRC; these externalities

are factors peripheral to the direct production process, but may have significant impacts on the crop.

3. SUSTAINABILITY

To provide a sufficient and sustained supply of woody biomass for more sophisticated energy uses at reasonable cost and in an environmentally sound manner requires the application of highly specialised short rotation crop systems. The design of sustainable biomass projects involves multi-disciplinary consideration of economic, environmental, social and technical considerations, some of which are external to the knowledge base of a projects terms of reference. Failure to address all aspects could place a project at risk in either the planning or operational phase, therefore the involvement of all potential stakeholders is required to develop a broad understanding of the issues involved.

Bauen (2001) considers that biomass will represent an important sustainable energy source in industrialised countries only if it will be able to supply the energy vectors demanded by modern energy services based on environmentally and economically sound fuel chains. He considers that in the case of energy crops, mechanisms need to be devised in greater synergy with energy and environmental policies that encourage farmers to grow viable biomass energy sources in a sustainable manner.

Mead (2000), suggests that energy production in Europe is likely to be of secondary consideration behind ecological and social reasons for planting. He also considers that despite a need for firewood in developing countries, purpose grown crops for fuel are grown, but multi-purpose agroforestry tree species and systems are used.

4. DRIVERS

Various social, economic or environmental forces often provide the impetus for the development of new technology or industries. While these drivers may be quite specific in some instances, many are invariably inter-related and have a collective influence on the development process. There are global, national and regional drivers for sustainable bioenergy production from short rotation crops including climate change, electricity demand, greenhouse gas reduction, fossil fuel substitution and land degradation.

Climate change is probably the most pervasive global environmental problem facing mankind, with the potential for damage to habitats, biodiversity, food production and economic development. The latest Inter-governmental Panel on Climate Change report predicts that global average temperature are likely to rise between 1.4 and 5.8 degrees Celsius over this century, depending on the amount of fossil fuels consumed (IPCC, 2001).

Rapid technological advances in the electronics industries over the last 30 years have escalated global demand for electricity, and coupled future social and economic development to the reliable and sustained supply of energy. Population growth has exacerbated these demands for energy and consumer items. However electricity generation accounts for nearly 40 percent of man-made CO₂ emissions worldwide, mostly due to reliance on fossil fuels such as coal, oil and gas.

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Industrialised nations must substantially reduce their CO₂ and greenhouse gas emissions under new international agreements such as the Kyoto Protocol. The use of renewable energy production will assist achieving emission reduction targets while maintaining energy requirements for social and economic development. Bioenergy produced from sustainable biomass resources is internationally recognized as a renewable energy source with no net emission of CO₂, the main greenhouse gas contributing to global warming.

Biomass production can also offer significant environmental benefits such as greenhouse gas reductions through substitution of fossil fuels, repairing land degradation and carbon sequestration. In New Zealand, the running down of the Maui gasfields will provide opportunity for development of alternative energy supplies including SRC. In Australia, salinity will be one of the main drivers for extensive revegetation of large areas of agricultural land, and short rotation crops will play a major role in the development of new rural industries. The direct and indirect influence of the Kyoto protocol is reflected in government initiatives in both Australia and New Zealand.

5. WATER MANAGEMENT

Fresh water resources are often finite, and demand for different uses may exceed supply in many countries. Rapidly increasing population growth rates, and economic and social development will force both current and future generations to be far more efficient in their use of water and other natural resources. The threat to lake water quality from point and diffuse sources is becoming an important issue in the central north island of New Zealand.

As the security of long-term water supply decreases, and its cost increases, agricultural, industrial and domestic strategies must be developed to minimise total water use and avoid waste. Irrigated agriculture accounts for over 80% of Australia's total annual water use, therefore efficient irrigation practices to minimise application loss (by direct evaporation, deep drainage or run-off) requires priority development.

The reclamation and productive reuse of wastewater could potentially provide a significant method of reducing total water requirements of society, while contributing to economic development and environmental protection. SRC may play an important role in some water management issues.

5.1. Water quality

SRC can play a role in riparian management as a filter strip or area of vegetation for removing sediment, organic matter, nutrients and other pollutants from runoff and drainage water. Native vegetation in riparian zones often contains the richest concentration of biodiversity in many landscapes, and requires protection from saline inputs. On cleared agricultural land, trees may also stabilise streambanks, and reduce water temperatures.

Roygard (1999) compared the performance of willow and two eucalypt species (*E. saligna*, *E. nitens*) in a dairy farm effluent study. Only willow maintained leachate nitrate concentrations below the New Zealand drinking water standard throughout both the winter and summer periods. Although the eucalypt species produced more biomass

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than willow, the author considered willow was the best species because of its better control of leachate moving beyond the root-zone.

5.2. Salinity

Control of salinity is one of the major drivers for revegetation and use of short rotation crops in low rainfall (300-600 mm) areas of Australia. Extensive clearance of deep-rooted perennials for annual agricultural crops over the last 100 years has changed the hydrologic equilibrium. Increased infiltration of rainfall has raised water tables and mobilised otherwise harmless stored salts to discharge to the surface in the most productive lower parts of the landscape. It is estimated that over 5 million ha of land has been damaged so far, and this area will rapidly increase unless urgent action is taken to ameliorate the problem. Current estimates predict over 17 Mha will be affected by 2050 (National Land and Water Resources Audit, 2001). Increased salinity in river systems is a major problem in water catchments and is also causing loss of biodiversity, amenity and damage to infrastructure.

Although complete revegetation would prevent further profile recharge, it is a costly solution. Extensive investment and development work by CALM and the Oil Mallee Company over the last 10 years has created a significant SRC resource (Bartle and Shea, 2002). There are now 28 million mallees planted by over 1000 farmers in the Western Australian wheatbelt. Use of belt or alley farming systems rather than woodlots has been preferred to integrate mallees with existing agricultural systems, maximise farmer acceptance and achieve best performance. Belt planting has the potential to increase mallee yield by capturing additional water to direct rainfall from lateral roots occupying adjacent cropland, surface run-off, and groundwater flows (Bartle and Shea, 2002).

Western Power Corporation has commenced final commissioning of a \$10 million demonstration scale integrated mallee processing (IMP) facility near Narrogin. The plant will handle 20,000 tonnes of mallee feedstock a year, and produce 700 tonnes of activated carbon and 200 tonnes of eucalyptus oil, plus have an electrical generation capacity of 1 MW. It will take several months of trials before IMP is proven commercially viable. Using cautious assumptions of market prospects for eucalyptus oil, it is estimated that up to 9 full scale plants (100,000 tonnes/yr) could be constructed in the WA wheatbelt. This will treat only a small part of the total affected area. Further R&D is required on a mallee harvester and systems to efficiently deliver biomass feedstocks to processing plants, and alternative species / products to provide financial incentive for further large scale environmental tree planting in other parts of Australia.

The scale of the salinity problem will require land treatments that can be rapidly deployed across millions of hectares of farmland. There is some hydrologic debate over the interaction between landscape positioning of trees and the proportion of catchments that need to be replanted with perennials to control recharge. Phase farming with trees (PFT) has been proposed by Harper *et al.* (2000) as another option for salinity control in lower rainfall zones of southern Australia. The concept requires growing trees at high planting densities in short rotations (3-5 years) to de-water soil and reduce recharge while also improving soil structure and producing wood fibre or biomass for “green power” generation. High tree water use can rapidly de-water soil profiles to several metres depth, creating a buffer of dry soil which may be refilled during the subsequent agricultural phase (5-20 years).

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A demonstration trial to determine if water depletion rates could be accelerated by species selection and silvicultural management has been established near Corrigin using various species and stocking densities. Soil water content beneath *E. occidentalis* planted at 4000 stem/ha has been depleted to 4 m after only 20 months growth. Phase farming with trees appears to be a promising development for de-watering soil profiles, reducing recharge to groundwater and lessening the risk of salinisation in agricultural landscapes. Robinson *et al.* (2003a) discuss technical and economic issues which may impede broad scale adoption of this radically new farming system employing SRC. These included costs and methods of establishment, harvesting, stump removal and potential markets for products.

The integration of oil mallee into agricultural production systems in Western Australia or using eucalypts with PFT are excellent examples of using SRC to remediate many environmental problems such as salinity, erosion and loss of biodiversity.

5.3. Wastewater

Population growth has increased the generation of both solid and liquid wastes from society, however many communities still rely on the removal and dilution of their treated effluent by discharging into nearby rivers or oceans. Degradation of those waters and associated ecosystems has greatly increased with population expansion and industrial development, however environmental and regulatory pressures have now forced many local authorities responsible for effluent treatment to consider alternative land application options, or use expensive tertiary treatment processes.

Wastewater arises from municipal, industrial and agricultural sources, and critical water quality issues (including nutrient content, salinity, SAR, pathogens, heavy metals) affecting suitability for use in irrigation varies widely. Research since the early 1960's indicates that wastewater irrigation of forests and plantations is potentially an effective low cost treatment option and a productive re-use of wastewater if sufficient land is available close to sewage treatment plants. Effluent irrigated forestry (EIF) presents a disposal option that provide environmental benefits and co-products which avoid the human food chain, while reducing the requirement for expensive secondary treatment and disinfection. The scale of EIF plantations is ultimately limited by the volume of wastewater available.

Much of the pioneering knowledge on species performance and silviculture in irrigated plantations in southern Australia was gained from trials established in Victoria during 1972–1980 (Stewart *et al.*, 1982, 1988). These trials screened a wide range of eucalypt species, but willows, poplars and radiata pine were also tested. The excellent growth responses in these trials prompted larger irrigation projects along the River Murray in South Australia, and Alice Springs for firewood (Stewart *et al.*, 1986). Nicholas *et al.* (2000) reported on the performance of tree species in a number of trials using wastewater irrigation, and concluded that *Eucalyptus* species should be considered as an alternative to *P. radiata* for waste water schemes in New Zealand.

Nicholas (2000) reported that after studying research trials in New Zealand and Australia that were established in the late 1980s and early 1990s to investigate the opportunity for land treatment using a range of hardwood species, very few of the research findings had translated into larger scale operations. This did not seem to be the

consequence of the lack of species or research knowledge, but rather the lack of commercial utilisation of the biomass produced. He suggested that future land treatment schemes should be associated with a utilisation processor to make use of the ability of selected hardwoods to rapidly produce substantial amounts of biomass and efficiently recycle or pump land treatment elements. Further integrated systems research was required on the commercial realities of effluent systems, especially for the tree crop, and its long term viability as an economic land use.

Wastewater-irrigated agricultural and tree crops share sustainability issues relating to water and nutrient balances, salt in the soil profile, soil sodicity, and effects on groundwater. Duncan *et al.* (2002) have recently reported results from nine flood irrigated eucalypt trials in northern Victoria. A range of water sources and qualities (low salinity channel water to high salinity groundwater to nutrient-rich municipal effluent) were applied to four eucalypt species at each site (*E. camaldulensis*, *E. globulus*, *E. grandis* and *E. saligna*). Strong correlations between the salinity of the irrigation water and the development of salinity, soil sodicity, foliar chloride accumulation and tree growth rates were observed. Where the irrigation water was highly saline (4.0 to 6.9 dS/m), salt accumulation has occurred throughout the soil profile, and growth of all species was significantly reduced. Any potential negative impact on tree growth appear masked by the beneficial effects of the additional nutrients in the municipal effluent at one site as growth rates to age 6 years are amongst the highest recorded in southern Australia. The authors questioned the environmental sustainability of eucalypt plantations irrigated with low quality water.

Maintenance of tree growth rates and site productivity is crucial to achievement of desired social, economic and environmental outcomes, the development of markets or local industry to use forest products, and continuation of this method of waste disposal. Many effluent irrigated forestry (EIF) trials conducted by forestry research organisations have placed too much emphasis on the production of traditional forest products, rather than investigate alternative product options such as bioenergy or environmental credits. Some projects in drier environments have placed significant importance on maximising growth rates with irrigation applications up to rates of potential evapotranspiration (water disposal), rather than applying smaller volumes of effluent across larger areas to address sustainability and market development issues (McGuire *et al.*, 2003). Wastes will remain a perpetual and increasing problem to society, and economic and environmentally friendly options such as energy production from biomass need greater publicity and investment support.

6. NUTRITION MANAGEMENT

6.1. Nutrient stripping

Short rotation energy forests offer a mechanism for nutrient capture in land treatment systems, with most interest in the uptake of nitrogen. Because total biomass production is closely associated with nutrient uptake, the *Eucalyptus* genus is usually considered because of its fast early growth and higher wood density when compared to other candidate species such as radiata pine, poplars or willows.

To determine potential rates of nitrogen uptake Nicholas (2003) studied relevant studies in New Zealand and Australian literature. Nitrogen uptake values range from 38 to 217

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kg/ha/yr for effluent irrigated plantations and 30 to 83 kg/ha/yr for rain-fed plantations. The highest value of 217 kg/ha/yr was from a plantation with extremely high rates of effluent irrigation and was not considered typical of a “normal” treatment system. Based on the literature reports for rain-fed plantations, and expected increase from effluent treated plantations combined with high stockings and younger rotations than used for conventional forestry, Nicholas (2003) considered that 100 kg/ha/yr of nitrogen uptake could be a reasonable estimate for a young eucalypt plantation (depending on site, growth rate, species, planting density, rotation and loading rates).

Du Toit and Scholes (2002) determined that the nutrient pool of a short rotation of *E. grandis* was rich in potassium and magnesium indicating that the system was well buffered against nutrient depletion in the short and long term.

Noble and Herbert (1989) report that for 10-year old *E. grandis*, analysis of the nutrient removal (based on published plant and soil nutrient concentration values) by different components of the above-ground biomass indicated that harvesting the timber (sapwood and heartwood) and the timber and bark resulted in a 31 and 76% removal of nutrients from the site respectively. Of the total Ca content on the above-ground biomass 75% is located in the bark.

6.2. Nutrient sustainability

Guo and Sims (2001a) consider that nutrient cycling in a short rotation forest system can be manipulated to give sustainable biomass production. They report that phosphorus, magnesium and nitrogen accumulated more than their initial amount in the litter, particularly under three year old stand irrigated with effluent. Sims and Riddell-Black (1998) suggested that the application of effluent on SRC, is necessary to create a sustainable land use by the application of nutrients to avoid the problem of nutrient stripping from repeated harvests and biomass removal from SRC cropping.

Tolbert and Wright (1998) found that at a research scale no differences were found in erosion and movement of nutrients from annual row crops, switchgrass and tree crops with and without a cover crop in the initial year of establishment. They considered that research and watershed-scale case studies on different soil types, in different regions and to match tree species with specific site characteristics and management regimes will help determine whether research-scale results can be used to predict effects at larger scales and to identify best management practices to minimise environmental effects while maximising yields.

Sims and Riddell-Black (1998) suggested that SRF, the closest of the biomass fuel crops to full commercial production has been identified as having several characteristics which make it potentially useful as an outlet for biosolids. A 6-year research programme into its use as a fertiliser has resulted in an operators manual which aims to assist biosolids managers to assess the value of adopting SRF into biosolids recycling operations.

6.3. Residues

Guerrini *et al.* (2000a) report that the use of iron slag, dregs and grits, sludge, extinct lime and wood ash on eucalypt plantations in Brazil resulted in growth increases ranging from 20-70%, depending on site quality. Guerrini *et al.* (2000b) suggest that the

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application of wood ash and pulp and paper sludge to eucalypt plantations can replace chemical fertilisation and provide significant growth benefits. Ash residues from bioenergy plants may be converted to fertiliser or spread among SRC to maintain nutrient availability.

6.4. Rehabilitation

Kuiper (2000) reported that salt uptake by 16 different willow varieties after sludge application showed a significant clonal difference in salt uptake, *Salix viminalis* and *S. fragilis* had the highest salt uptake.

Robinson *et al.* (1999) report that a willow clone accumulated significantly more cadmium than two poplar clones, which themselves were not significantly different. They considered that both poplars and willows have excellent potential for cadmium phytoremediation, and that if the results from pot trials were realised in the field, then a single crop of willows could remove over 100 years worth of fertiliser-induced cadmium contamination from pasture lands in New Zealand. Robinson *et al.* (2003b) outline a case study in New Zealand on the use of willow, poplar and eucalypt on a sawdust dump to evaluate their performance as phytoremediation crops.

Tree crops on landfills can minimise water percolation into landfill waste by transpiration of soil water and prevent soil erosion by interception of rain fall and reducing the splash effect. They can also supply other benefits which include aesthetic appeal, sequestration of greenhouse gases, reduced construction and operation costs as well as the creation of wildlife habitat. The Ecolotree Cap is a patented phytoremediation system that consists of carefully designed cover soils planted with perennial trees and understorey grasses. A possible revenue stream from bioenergy could also be realised (L. Licht pers comm, 2002).

Nicholas *et al.* (2000) report on the evaluation of eucalypt species for land application of pretreated landfill leachate. Five *Eucalyptus* tree species were evaluated (*E. botryoides*, *E. ovata*, *E. camaldulensis*, *E. grandis* and *E. globulus*). *E. globulus* proved to be the most productive species with a positive effect of effluent application on tree diameter growth. Foliage analysis also showed that *E. globulus* had some potential for boron accumulation.

7. CROP MANAGEMENT

7.1. Health

Makeschin (1999) suggested that although there was sufficient information on optimal management regimes, plantation problems were mostly caused by pests and rusts, leading to the conclusion that clone mixture plantations are recommended to decrease infestation probability. Also ecological effects of plantations were considered positive as long as key principles of sustainable forest land use are kept. He felt that future research needs are needed to increase knowledge for both economically viable as well as ecology and biomass production.

7.2. Biodiversity

A major period of development of new perennial woody plant crops is now emerging. If we were to turn to exotic species as the source of new commercial crops probably hundreds of species would need to be screened to locate several that may have commercial value. In such a process some of those tested may have potential to become weeds and may escape from cultivation to express their weed habit. For example, the desirable attributes of low palatability and rapid regeneration could be the makings of a successful weed. Weeds can cause economic loss through the need to impose controls or suffer the loss of use of land. Woody weeds also present a risk to the nature conservation value and biodiversity of our native bush.

Weed risk would be greatly reduced if new woody crop development first considers the potential value of native species. There is little risk of native species becoming weeds because they have evolved within the checks and balances of local ecology.

The oil mallee project has embraced this principle. Eucalyptus oil was harvested in the WA wheatbelt in small amounts several decades ago, but there are now known to be more than 20 mallee species with commercial oil potential. Species could be selected to suit particular environmental niches, to provide particular oil constituents or to meet particular management needs such as low palatability (negating the need for fencing).

7.3. Mixtures

Makeschin (1999) suggested that mixtures (of clones) should be included in management operations because of stand health benefits

Khanna (1998) reports that *Eucalyptus* and *Acacia* are two tree genera that are commonly used in industrial plantations and as components of agroforestry systems in southeast Asia. These fast-growing trees are mostly grown in monocultures. However, questions are now being raised about the long-term sustainability of their growth as well as their effects on site quality. A significant amount of that N is transferred to adjacent eucalypts, thereby improving the growth and nutrition of the eucalypts, and outweighing the detrimental effects of competition for light and water.

Hunt and Beadle (1998) report that whole-tree water use in 4- and 8-year-old plantations of *E. nitens* in the presence and absence of *Acacia dealbata*. *A. dealbata* was not limiting water availability in the 8-year-old plantation but was restricting water use (and by definition the productivity) of *E. nitens* through competition for another limiting resource, probably light. *A. dealbata* crowns occupy a large area of the overstorey canopy, reducing the size of the eucalypt crowns.

Schubert *et al.* (1988) report on improved productivity from eucalypt/legume mixtures, where *E. saligna* were 25-63% taller and 28-65% larger in diameter when grown with *A. melanoxylon* or *Paraserianthes falcataria* compared to pure stands.

8. ECONOMICS

Dedicated bioenergy crops are a minor part of the international forestry scene, largely because they are regarded as an expensive crop if grown solely for bioenergy, their establishment in some countries has relied on government subsidy to initiate planting programmes.

Pandey and Masoodi (1996) consider that the viability of SRF depends on the achievement of a sufficiently high yield to give a large enough energy output/input ratio to carry the costs of the scheme and for the energy produced to be competitive in price with equivalent energy obtained from other sources. They considered that SRF has to stand on its own feet as there are a number of major factors working against it in the form of internal economics of the schemes and from outside.

- The need for low cost land
- The development of cost effective methods of propagation
- The development of methods of mass planting cultivation, crop treatment and harvesting
- The cost of additives, fertilisers and pesticides
- The development of fuel processing techniques
- Competition for alternative use of land
- Alternative use of the product.

Vandenhove *et al.* (2002) suggest that the profitability of SRC production largely depends on crop yield, harvesting method, and price of the delivered biofuel, labour and machinery cost playing a minor role. They found that the IRR of 5% at the production side is only obtained with high biofuel prices(40EUR/t) and a biomass yield of at least 6t/ha. On the conversion side they consider that heat and power plant investment schemes were only profitable when industrial energy prices are considered. Systems are not viable at lower domestic rates with IRR being always smaller than the 10% required for industry in Belarus. Large-scale heat conversion systems are the most profitable and revenue may be considerable with the IRR between 16% and 59%. They considered that electricity routes are usually unprofitable, and that waste disposal costs are only a fraction of the total costs and revenue.

Linville and Betters (1997) report from a study of the economic feasibility of short rotation intensive culture tree plantations, that numerous wood biomass production scenarios were evaluated using standard economic criteria. All scenarios gave negative economic results even when including a federal subsidy programme. The best two scenarios, one irrigated and the other not, applied herbicides and fertilisers, and produced wood chips as a product using a ten-year rotation. Despite these assessments, they suggested that rural land owners in the region (eastern Colorado) may still wish to consider these plantings given their substantial environmental and sustainability benefits.

Turhollow (2000) suggested that biomass energy (willows, poplars and switchgrass) could potentially be produced from buffer strips. Economic analysis was conducted on five scenarios. He found that willow was highest cost in all scenarios, poplar was intermediate in cost in three scenarios, Poplar and switchgrass were similar in cost in two scenarios and switchgrass was lowest in cost in 3 of the scenarios evaluated.

Börjesson and Berndes (2001) conclude that the environmental benefits from a large-scale introduction of multi-functional biomass production systems in Sweden could be substantial,

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as the negative environmental impact from current agricultural practices and municipal waste treatment, as well as from current forestry practices, could be significantly reduced. Examples of benefits are reduced nutrient leaching and soil erosion and increased cadmium removal from agricultural land, improved nitrogen balance and reduced acidification in forest ecosystems, and improved treatment efficiency of polluted waste waters. When the economic value of such services is considered, the cost of large quantities of biomass could be reduced by more than 50%, thus affecting future market conditions for biomass.

Abrahamson *et al.* (1998) felt that for SRC bioenergy crops of willow and/or poplar to be commercially successful must be ecologically and environmentally sustainable. They also recognised that economic viability was important. They suggested that the environmental and ecological benefits of the system should act as a catalyst for developments needed to overcome the economic constraints of the system.

9. CO-PRODUCTS

The relatively low cost of fossil-fuel energy in Australasia is likely to limit the development of biomass energy unless consumer awareness and demand for Green Power significantly increases, government subsidies are reduced or fossil fuel reserves are totally exhausted (NZ – post Maui). Crops solely grown for energy purposes are expected to be a more expensive biomass source than residues from higher value crops such as wood or sugar directly available at utilization plants.

However SRC may provide supplementary resources in niche situations to establish additional generation capacity or sustain demand when cropping residues are exhausted. Large quantities of biomass residues from agricultural production may be available only for restricted time periods each year eg bagasse from sugar cane, thus restricting year round supply.

The greatest SRC prospects in Australia are for crops that yield other commercial products (eucalypt oil, activated carbon) or provide environmental benefits as well as bioenergy. Some forestry agencies are exploring biomass options for cofiring and charcoal with electricity generators and steelmakers.

Stucley (2001) noted that the commercial position of bioenergy may be enhanced when other value added products are also produced, but projects must be driven by a strong understanding of the markets for co-products. He outlined several complementary products considered for the Western Australian oil mallee project such as: charcoal, activated carbon, oils such as eucalyptus oil and pyrolysis products (including liquid fuels). Complementary values were also identified such as: water control, salinity mitigation, increased employment, community cash flow, and development of associated industries (nurseries).

Several eucalypt species produce high quantities of leaf oil, the most important of which is 1,8-cineole. *Eucalyptus* oil currently has numerous small markets, especially in pharmaceuticals, fragrances and food flavourings. Significant market opportunities for eucalyptus oil exist in industrial degreasing and solvent applications from phasing out of trichloroethane under the Montreal Accord to arrest ozone depletion.

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There are global trends to substitute the use of renewable resources for a variety of products, particularly those currently derived from the petrochemical industry. There is renewed interest in Australia on the production of renewable biofuels from wood biomass. These include ethanol and methanol for use as liquid transport fuels. Lignin residues from the fermentation process for ethanol production can be used for electricity generation (Enecon 2002). A variety of chemical products may be derived from bio-oil from wood pyrolysis. Innovative new technologies and processes are developing other new products from biomass, including plastics, pesticides and other high value chemicals.

Large-scale viability of woody SRC will require commercial use of wood and residues. The only markets able to absorb the potential scale of wood production are the world markets for woodpanels and paper, and domestic energy markets. The integrated mallee processing project in Western Australia is an example of activated carbon and energy co-production, with eucalyptus oil as a by-product. Charcoal is produced initially, but further steam or acid treatment produces activated carbon.

The sustainable production of charcoal from extensive eucalypt plantations at V&M FLORESTAL in Brazil directly contributes to reducing the greenhouse effect by carbon sequestration and substitution of coking coal. Charcoal is supplied to its parent company (VMB), an international company producing seamless steel pipes. Production of the "Green Tube" contributes for environmental preservation, as an average of 2.5 tons of CO₂ are removed from the atmosphere for each ton of steel produced. Total annual production is just over 1 million m³ of charcoal from the V&M FLORESTAL estate of 127,000 hectares. Wood tar is also collected from the furnaces and about 20 tonnes/month is exported to Japan and the USA for medicines. These extensive plantations ensure self-sufficiency in charcoal, while also creating regional job opportunities and economic development (Nicholas 2003).

Markets are developing for other products that are tradeable commodities which may assist the establishment of SRC and the cost competitiveness of bioenergy production.

The establishment of tree crops to provide fuel for bioenergy plants also provides an opportunity for carbon sequestration in the standing biomass developed in SRC or plantations, and in the root biomass of coppiced crops. The development of Carbon trading and market values for other environmental services (including salinity and erosion mitigation, soil conservation, land asset protection, biodiversity, water quality protection, beneficial wastewater re-use) are currently being investigated, and could generate significant investment for development of new "green" rural industries.

10. EXTERNALITIES

10.1. Public awareness

The potential for bioenergy has been overshadowed by more widely publicised renewable energy technologies such as wind, solar and hydro, and retains an outmoded image in comparison to these "clean green" technologies. Some of these alternative technologies have a distinct competitive advantage over biomass, as they principally require only technological and financial investment to commence energy production. The short payback period is attractive to investors compared to longer return period and risk required to establish significant area of biomass resources such as SRC.

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Although all renewable technologies offer opportunities to substitute for use of fossil fuels, these other technologies do have important limitations such as lack of wind/sun/rain which may restrict their suitability to specific geographic localities to ensure continuous supply. Some of their other limitations are also poorly publicised:

- No sequestration of CO₂ into long term carbon stores
- No use of waste or residues. Waste to energy systems are often economically attractive, and helps resolve municipal waste disposal problems, fosters recycling, reduces landfill needs and provides opportunities for cogeneration of energy
- No use of wet waste streams from sewage treatment plants or other industrial sources
- Low employment creation, particularly after plant establishment
- Hydro schemes require water storage and diversion of river systems, reducing environmental flows, with consequent effects on riparian biodiversity and habitat

Bioenergy has enormous potential to provide renewable energy with low greenhouse impacts and well as a range of economic and environmental benefits. There are strong public perceptions linking biomass and bioenergy production with use of firewood and the smell of woodsmoke from inefficient combustion heaters and stoves. However biomass can be converted efficiently to a variety of products- heat, electricity, transport fuels and substitutes for plastics and petrochemicals.

There is an abundance of well designed successful bioenergy projects around the world, yet in most cases these projects rarely create more than only localized public interest. Increased public awareness and support is crucial to achieving widespread acceptance and application of bioenergy in the energy sector, and meeting social and environmental sustainability criteria are key elements in achieving this support for a radical shift in energy use.

Stronger promotion of the concepts of using bioenergy and the economic opportunities is urgently required to facilitate public acceptance and stronger uptake. These may include public awareness and education programs, and multimedia coverage of activities within the public domain, particularly “good news” stories. Public awareness of the potential for using biomass is quite limited – NIMBY resistance to the aesthetics of wind projects gets all the headlines. Swift responses to current newsworthy events should spread the word about “the alternative option”.

10.2. Land ownership

To qualify for carbon credits under the Kyoto protocol, plantations must have been established since 1990 and meet other eligibility criteria which effectively preclude replanting of existing forest land or plantations established prior to this date. The most inevitable consequence of qualification for carbon credits is that plantations will need to be established mainly on existing cleared agricultural land. The suitability of this land will vary greatly, although agriculture is often the dominant land use on the best available soils. Much of this land invariably had poor natural woody vegetation, therefore was easy to clear. Previous land use may positively or negatively affect site fertility according to the history of fertilizer application and nutrient removals by crops. Sites eroded by wind and water often has reduced productivity due to loss of valuable topsoil.

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Farmers own most land in rural areas of Australia suitable for SRC, however farm incomes have been quite variable depending on climate. Annual returns may be quite high, and will conflict with potentially low returns over several years, even for SRC. More intensive management is often an attractive option if land costs are high, as opposed to planting more area on cheaper land. Diversification of farm production and income may reduce the need for government drought relief.

Social characterisation of participants (and non-participants) is often the most powerful explanatory variable determining adoption of novel technologies, especially those that involves some degree of risk. The adoption of new technology or crops by farmers is facilitated by good extension services, however it is sometimes important to attract and promote these technologies to the key or innovative farmers within each district. The initial demonstration must be successful to encourage other landholders to spontaneously adopt these alternatives to current land uses.

The establishment cost and alternative annual revenue foregone on land occupied by tree crops imposes an economic constraint on the rate of adoption of tree crops by farmers. Sharefarming arrangements have been developed in the blue gum industry where an off-farm investor shares the growing costs and the harvest revenue with the land owner. Another way to facilitate adoption of tree crops is to select short rotation tree crops where harvest revenue starts early and comes regularly thereby maintaining farm cash flow and helping the farmer finance his own investment in tree crops. On a whole industry level the investment required for short rotation tree crops will be less than long rotation crops and therefore a short rotation industry should be more readily developed. Oil mallee is ready for harvest by age 4 and can then be cut on a two year cycle.

Bioenergy may provide significant economic opportunities for local communities such as regional jobs and industry creation. Where bioenergy supports tree planting in rural areas, a number of positive social and environmental impacts at various scales may be obtained that cannot be achieved through the use of other forms of renewable energy. The social fabric of many rural communities depends on employment options in their local areas, particularly opportunities for youth employment. Growing, harvesting and transport of SRC are permanent, ongoing activities after plant establishment. Bioenergy projects may have significant economic multiplier effects through indirect employment and support industry creation.

Other effects are broad and long term, and are difficult to quantify in economic terms, such as tourism, aesthetic and amenity values (dust/ noise). Sustaining agricultural production through mitigation of dryland salinity and soil erosion may be of immense value to future generations, as world population growth will require increased food production from a shrinking land base.

10.3. Research and Policy

Good scientific research is a prerequisite to the development of new technology, but not an end in itself; there must be a strong link to extension, economics and policy formulation. The adoption of new technology or crops by farmers is facilitated by good extension services, however it is sometimes important to attract and promote these technologies to the key or innovative farmers within each district. Efforts must be

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directed to ensure the initial demonstration is successful to encourage nearby farmers to spontaneously adopt these alternatives to current land uses.

The introduction of woody perennials into agricultural landscapes with crops and livestock, will involve tradeoffs in current production, and may take several years to generate financial returns. There must be strong market prospects for products, and a favourable economic outcome to any new venture before it will achieve broad scale acceptance and uptake. Complex technologies such as SRC may need to rely more on supportive policies for their development, uptake and spread than less complex agricultural land use systems.

Research plus extension alone is often inadequate and clear policy development is needed to support such developments if they are to have any durable long-term impacts.

10.4. Harvesting

If Australia is to successfully produce bioenergy from SRCs, it will have to develop technology to achieve substantial cost reductions in harvesting and materials handling. The use of continuously travelling harvesters and coordinated bulk haulage methods employed by the sugarcane industry could reduce the cost of supplying woody biomass compared to conventional forestry harvesting. The European technology used in harvesting willow SRC is not suitable for Australian conditions. The willow is significantly different in form and wood characteristics from SRCs in Australia, where crops have heavy, branched crowns and higher wood density. Subsidies for European bioenergy make their harvesting and material handling strategies unsuitable for the economic environment in Australia (Rick Giles, CALM, pers comm.).

10.5 Scale

Salinity control was a major precursor to the establishment of 10000 ha of oil mallee plantings across the Western Australian wheatbelt. However the full extent of woody perennial cover required to control salinity in Australia is probably in excess of 20% of all agricultural land and may be as much as 40%. This assumes there is complementary use of herbaceous perennials and engineering treatments on discharge areas. Such extensive revegetation will generate a very large volume of biomass, which will require very large volume markets to minimize risk of oversupply (Bartle and Shea, 2002). There is now capacity to supply up to 30% of the current world markets for eucalyptus oil, thus new markets or products must be developed to provide financial returns to farmers.

Bartle (2001) forecast that extensive salinity control would not be achieved without very large-scale penetration of electricity and transport fuel markets. There are significant benefits from economy of scale in larger power plants, with the per-megawatt capital cost for a 30 MW plant only 30 percent that of the cost for a 1 MW plant (C. Stucley, pers comm.). This has important implications for the cost of electricity from a biomass plant, and its ability to compete with other energy producers.

Unfortunately these economies of scale do not apply to biomass plantings. A 30MW plant requires supply of about 300,000 tonnes of biomass per year. To immediately start operating a plant of this capacity, a large resource must be available from the outset.

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Processing plant construction will not proceed until an adequate size resource to supply sustainable volumes is available. Residues from plantations, sawmill waste or others sources could be used as an interim fuel source, however harvesting residues from native forests may not be acceptable to the environmental movement. Greatest processing efficiency is achieved with uniform input material (e.g., moisture content).

Processing plant will generally be located in rural areas because the low value of the residue precludes transport to distant centres. In Western Australia, the smallest operational plants are likely to require 100 000 tonnes/year of feedstock (leaf and wood). In alley planting configuration this will require 50 000ha planted on 50 m spacing. A viable 50 km transport radius requires only a modest level of adoption to produce the volume required for a minimum plant size (Bartle and Shea, 2002)

10.6 Certification

Kuiper (2000) reports that the Dutch FSC for plantation forest requires that in all plantations at least 10% of the area is planted with mixed indigenous tree species. Half that area (i.e., 5%) either located at the edges, along water courses or adjacent to more natural areas is not to be harvested at all.

10.7 Government policy

In 2001, the New Zealand government released the National Energy Efficiency and Conservation Strategy. This has a policy of continuing improvement in New Zealand's energy efficiency and in progressive transition to renewable sources of energy. It has a target for:

- (i) *Energy efficiency*: At least 20% improvement in economy-wide energy efficiency by 2012.
- (ii) *Renewable energy*: Increase renewable energy supply to provide a further 30 PJ of consumer energy by 2012.

The Australian Government introduced the Mandatory Renewable Energy Target (MRET) in April 2001. The Renewable Energy (Electricity) Act 2000 requires the generation of 9,500 gigawatt hours of extra renewable electricity per year by 2010, enough power to meet the residential electricity needs of four million people. Electricity generators are required to obtain 2% of their energy from renewable sources, via a mandated market for the creation, trading and surrender of 1 MWh Renewable Energy Certificates (RECs) from accredited renewable energy sources. A \$40/MWh penalty applies for failing to surrender the required RECs. Australia also has a national "Greenpower" electricity marketing scheme that complements MRET and provides a voluntary premium price for renewable electricity produced with predetermined environmental and sustainability credentials.

Increased hydro, wind and waste to energy projects are meeting MRET targets, and obtaining RECs, however few biomass projects are being planned. Interpretations of the regulations currently limit the eligibility of woody energy plantations to receive accreditation, prompting concern among proponents of SRC projects. The 2% renewable target under MRET has been recently reviewed and recommendations are under consideration by government.

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Australia has several programmes to support increasing use of renewable energy including remote power generation, alternative transport fuels. Bioenergy is generally a distributed source of energy, providing security and diversification of energy supply for electricity or liquid fuels. Reduction of electricity line transmission losses with increasing distance could reduce the overall level of electricity generation required.

11. CONCLUSION

A review of Short Rotation Crops (SRC) environmental and economic externalities has show that SRC can provide a multitude of benefits to the environment and economy en-route to bioenergy production. New Zealand and Australia have opportunities to capture many of these benefits. In the case of New Zealand, the strongest case can be made for using eucalypts in a wastewater context where the crop is designed as a nutrient stripper. However successful bioenergy conversion is not implemented to date, although forest processing residues are providing renewable bioenergy to the forestry sector. When a bioenergy market emerges, it will bring the investment and infrastructure of a bioenergy fuel market, providing an avenue for SRC utilisation.

Australia on the other hand has a very different scenario. The synergy of salinity mitigation, mallee eucalypts established for eucalypt oil production and conversion through the Integrated Mallee Processing plant at Narrogin in Western Australia producing activated charcoal and electricity have initiated a potential viable land use option. Based on this first plant, more plants are likely to be developed.

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