Promising resources and systems for producing bioenergy feedstocks

Short Rotation Coppice with willow in New Zealand

SRC willow offers an environmentally benign alternative land use for farmers, where reduction of nutrient leaching and run-off is an issue.

The use of the biomass produced is likely to be focused on the manufacture of liquid fuels and chemicals rather than heat and power, given New Zealand's energy situation.

Currently the only plantings in New Zealand are experimental trials and nursery scale yet growth rates and crop health are encouraging.

IEA Bioenergy

IEA BIOENERGY Task 43
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Short Rotation Coppice with willow in New Zealand

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KEY MESSAGES

SRC with willow has moved forward since 2004, when the first trials were established.

Parts of New Zealand, where adequate summer and autumn rainfall exist, provide excellent conditions for production from SRC willow. Soils in New Zealand are not expected to be a limiting factor.

Pests and diseases are not limiting factors to production from the preferred species trialed in New Zealand, but will need to monitored and managed.

New Zealand farmers possess the skills to implement proven methods of growing SRC willow, though site selection is important for success.

SRC provides opportunity to supply biomass in a cost effective manner. Key markets include cogeneration of heat and power, but the largest opportunity lies in fuel and chemical production.

Cover Images: SRC willow trial – Western Bays, Lake Taupo catchment

FOREWARD

In my view, the big new challenges facing humanity today are climate change and peak oil; the point where we have used more than half of the oil originally available on earth. While there is uncertainty over the extent and timing of these impacts, no business should ignore the threats to the status quo. What I know is that we won't return to oil at US$25 per barrel, and that some form of carbon cost will be imposed directly on use of oil.

The period beyond peak oil, and the high cost of oil, provide an opportunity to source economically viable alternative means of producing transport fuel. Biomass provides one of these solutions. Biomass can be sourced as a waste stream from current activities such as forestry. However, intentional biomass farming for fuel energy, on high quality land, providing high yields that can be easily managed, harvested and transported provides the way forward.

The scale of biomass required to replace oil is best expressed in terms of current wood requirements. The USA estimates it can only become independent of fossil fuel with biomass in the order of double the current demand for timber and pulp, while NZ has a similar view (in domestic demand for wood). The fact that all this needs to happen during the next 30 years provides an impetus to biomass production that few recognise, let alone act on.

Threats provide opportunities to those with aptitude and attitude. Dairy farmers are already benefitting indirectly from high corn prices driven by ethanol production in the USA. More directly, the opportunities for farmers to become energy farmers are becoming clear – we won't fill the energy gap by using forestry waste only.

I encourage farmers to look optimistically at opportunities provided by energy farming. Challenges do exist in making energy farming work here in NZ. The upside is that energy prices are rising, NZ needs to convert from fossil fuel, technology will actually enable more than fuel production from energy crops, and opportunities exist to sell biofuel.

Farmers do have the skills to adapt to this sector. This report is a tool to assist them to do that. It captures informaton from significant overseas experience, trial studies in New Zealand, and business interest and investment.

Kevin Snowdon

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EXECUTIVE SUMMARY

New Zealand is dependent on domestic and imported fossil fuels for heat and transport energy. Biomass currently only supplies a limited portion of primary energy, mostly as wood for heat in the wood processing sector. A key energy demand is liquid transport fuels derived from oil, which has been identified as both a risk and opportunity.

Short Rotation Coppice willow provides an opportunity to widen the sources of biomass for heat and transport fuels.

SRC willow is a sustainable land use in catchments where traditional farming land use reduces lake water quality through nitrification of the eco-system. SRC willow could also be used to treat waste water high in nutrient levels.

Site selection is important as SRC willow requires adequate and consistent rainfall to optimize productivity. Because SRC willow requires mechanical establishment and harvesting, it is not suited to hill country: rather it is a land use for low contour land.

This book summarizes key principles of establishment and management to ensure commercial success.

Key willow species suitable for growing in New Zealand are identified; *Salix viminalis* 'Gigantea', *S. purpurea* 'Irette' & 'Booth', and *Salix schwerinii* 'Kinuyanagi'

The likely productivity (from 3 years of growth) determined by trials to date is 16 odt per ha, with a range of 7 to 25 odt / ha.

Costs of production are estimated to be;

A key driver of SRC willow development is the need for land use change and reduction of nutrient leaching and run-off in two distressed lake catchments in the Central North Island of New Zealand.

1. INTRODUCTION

This handbook updates an earlier publication 'Energy Farming with WILLOW in New Zealand', produced in 2008 as part of MAF Sustainable Farming Fund (SFF) project 05/058 "*Energy Farming to Protect Lake Taupo (& Provide Sustainable Income for Threatened farms*"). Environment Waikato, Lake Taupo Development Company, Scion, Plant and Food Research and Maori land owners in the Taupo district contributed to the earlier work, while Salix Limited and IEA Task 43 have contributed to this update.

The main activities of the initial project were the establishment and monitoring of 5 ha of research and demonstration trials in the Taupo and Rotorua Lake catchments.

Much of the experience gained in the last six years is included in this report; Short Rotation Coppice with Willow in New Zealand.

Cultivation of willow for biomass is a new venture for New Zealand (NZ). However, there is considerable international experience in the cultivation, management, harvesting and utilisation of willow for biomass.

The focus for willow opportunities in NZ will initially focus on providing land owners a new land use option with a potential for revenue as land is forced to change to uses which have less nutrient leaching and run-off in two distressed lake catchments in the Central North Island.

1.1. New Zealand Energy situation

New Zealand uses ~817 PJ per annum of primary energy. Of this 93% (318 PJ) is from renewable resources; hydro (90PJ), Geothermal (159 PJ, Wind (7 PJ) and Biomass (60 PJ). Electricity generation in New Zealand has a high level of renewables (based of Hydro), which is increasing as geothermal and wind generation capacity is built. Renewables are 65 to 70% of electricity generation, depending on annula rainfall, and icreasing, with a target of 90%. Wind and geothermal development will cover not only new generatioin capacity, but also the retirement of old coal fired generation for the next 15 to twenty years.

NZ has extensivecoal resources and has relied heavily on gas for industrial heat and some electricity generation.

Our oil resources are small and we rely heavily on imported oil to meet our 276 PJ per annum oil demand.

Exploration for new oil and gas resources ais underway, and fracking has led to some increasae in gas production. NZ also has large methane hydrate deposists in its coastal waters which may be extractable as a gas resource in the future, although the technology to do this is still experimental.

Use of biomass for electricity generation does occur, on large wood processing sites, fueled by processing residuals such as sawdust and bark. It is unlikely that this will become widesprewad as there are readily available alternatives for electricity generation where the fuel is effectively free (wind, geothermal, hydro, solar). Niche bioelectricity developments, probably in remote off grid locations where biomass is cheap and grid connection expensive are possible.

The use of biomass for heat is lowly growing, but this is based off the use of cheap wood residue streams (wood processing, municipal wood wastes or forest harvest residues). Purpose growing biomass for heat production will be challenging.

On the other hand, oil is expensive, imported and not getting either cheaper or more plentiful. The cost of liquid fuels in NZ is dictated by the price of oil and the NZ / US dollar exchange rate. The annual bill for importing oil is in the order of $8 to $9 billion NZ dollars per annum ($6 to $7 billion US dollars).

Liquid fuels are our largest single energy demand, one which is growing steadily (~1% per annum), and which cannot be met from domestic supplies or resources. Thus we have a situation where the key area for use of biomass for bioenergy in NZ will be in the production of liquid fuels and chemicals.

However, there are no mandates or subsides for biofuels in NZ, with the only support being excise tax exemption of ethanol blended with petrol as E10. The ethanol used is largely domestically sourced and is manufacturedas a by-product in the dairy processing industry.

There is significant interest of development of Biomass to liquids (BtL) within the forest and wood processing industry and reasearch is underway at Scion, the University of Canterbury and by a number of independant developers.

Development of biomass to liquids will need to stand alone, on its own merits as a commercially viable business, two key componenet to this happeing are;

- Large scale low cost feedstock supply
- High yeild low-cost conversion technologies

The priority fuel demand is diesel, as this powers NZs primary industries (farming, forestry, mining, construction and the freight of its products) which are the backbone of the economy (Parliamentary Commissioner for the Environment 2010). Diesel demand in NZ is around 3.1 billion litres per annum and rising. If we assume that 230 litres of diesel can be made from each oven dry tonne of wood, we need around 13 million odt per annum (approx 31 million cubic metres of log) to meet just the diesel demand.

Our current total log harvest is 26.5 million m^3 per annum, with estimated residues of 3 to 4 million m^3. Therefore to make wood a significant contributor to liquid fuel demand we need a great deal of raw material and no single source will be able to meet all the demand. However, wood resources from a range of sources could collectively make a significant contribution.

SRC willow may well have a place in the supply of biomass to any BtL operation. It has been estimated that in the Taupo and Rotorua Lake catchments there could be up to 115,000 ha of land that is suitable for SRC willow (Hall et al 2010). If this land was placed into tyis use it could produce as much as 700,000 odt per annum (around 5% of the biomass needed to meet the diesel demand).

1.2. Overseas experience

Willow is already being used overseas as a dedicated energy crop, mostly to fire municipal heating plants producing heat and power. Sweden has more than 15,000 ha of Short Rotation Coppice (SRC) willow currently grown for biomass production and the UK has more than 1,500 ha of SRC willow established primarily for co-firing in coal power stations. The United States has an emerging willow industry with over 300 ha in experimental plantings. The International Energy Agency Bioenergy Task 43 (Biomass Feedstocks for Energy Markets) is dedicated to deploying knowledge of biomass crops including SRC. See www.ieabioenergytask43.org.

1.3. New Zealand experince

New Zealands SRC willow experince is limited to trials for biomass productivity. Plantings total less than 10 hectares.

1.4. Product uses

In addition to its use in co-firing and gasification for energy production, willow biomass represents a relatively low cost feedstock for the production of liquid fuels and biomaterials.

Converting woody biomass into a liquid fuel is a more difficult process than converting sugarcane or corn but the technology is available and is typically termed second generation biofuel technology. In terms of woody biomass willow is a hardwood and easier to convert to ethanol than softwoods, which make up the majority (95%) of NZ's production forests.

The ongoing research and large-scale demonstration of willow biomass crops supported by international research agencies, developments in the extraction and use of xylitol from willow biomass, and other chemical developments, are creating new opportunities for potential commercialisation of willow biomass farming in New Zealand.

1.5. The future

The development of a vibrant willow biomass enterprise has the potential to play an important role in diversifying and bolstering regional rural economies, increasing energy independence, enhancing environmental protection, and mitigating pollution problems.

1.6. What is Short Rotation Coppice (SRC) willow?

Short Rotation Coppice (SRC) crops are defined as woody crops such as willows, poplars, *Robinia* and *Eucalyptus* with coppicing abilities.

Coppicing is the process of cutting trees down, allowing the stumps to regenerate for several years and then harvesting the resulting stems (Figure 1).

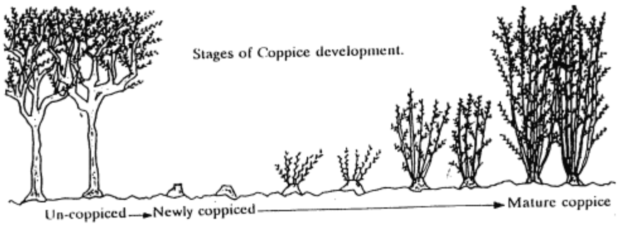

Figure 1. SRC willow cycle

The cut tree stump is known as a stool. The shoots are harvested on a rotational cycle. This means that they are left to grow for a certain number of years and are then cut, whereupon the whole process starts again. For willow, this period is commonly three years.

1.7. Is SRC willow for bioenergy new?

SRC willow has been grown for biomass for over 30 years (Figures 2) and there is a large amount of published scientific literature on such aspects as suitable clones, yields, management, pests and diseases, heat units and economics.

Figure 2: Harvesting Short Rotation Coppice (SRC) willow near Taupo, New Zealand, after 3 years regrowth on a stool.

1.8. SRC Willow - a new land use opportunity

SRC willow provides land owners with a new land use opportunity. There are many potential market routes for willow to contribute to farm returns, either directly as market products or indirectly as co-products (Figure 3).

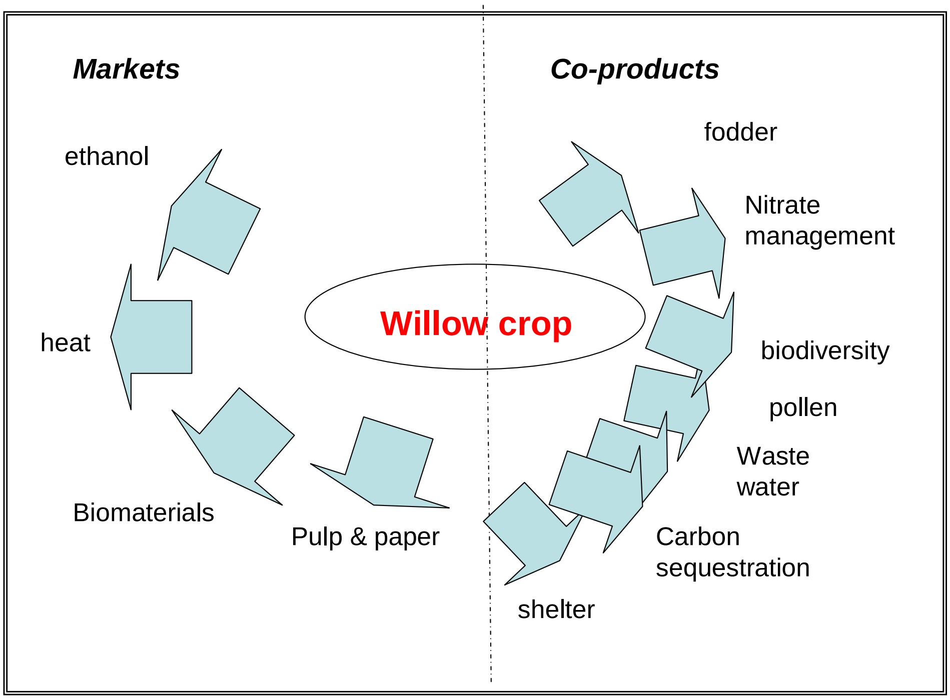

Figure 3: Market options for Willow Short Rotation Coppice (SRC)

It is envisaged that the primary use of willow biomass in New Zealand will be:

- **Ethanol** for fuel
- **Biomaterials**
- Fuel in co-generation plants (heat and electricity generation)

with secondary uses:

- Stock fodder.

The production of ethanol and biomaterials will be dependent on technology development

Ethanol for fuel is produced by breaking the fibre down into its sugar components, followed by fermentation of the sugars.

The biomass productivity of an SRC willow plantation is expressed in oven-dry tonnes per hectare per year (odt/ha/year). Estimations of willow productivity (10 odt/ha) and potential for conversion to ethanol (300 litres per dry tonne) suggest that around 110,000 ha of plantation land would provide biomass to generate ethanol sufficient to satisfy an E10 mandate for ethanol in blended fuels, and around one million hectares to replace petrol with ethanol at current levels of consumption (3.3 billion litres per annum).

SRC willow can be used as chips or in pellet form in combustion plants to generate heat or steam for electricity generation. SRC willow has been explored as an additional feedstock to augment supply to existing large cogeneration plants. Other opportunities exist to grow SRC willow for supply to smaller cogeneration facilities.

Willow leaves, small stems and bark are nutritious stock fodder, and may have anthelmintic (de-worming) benefits for stock.

2. ESTABLISHING SRC WILLOW CROPS

SRC willow involves planting cuttings at high densities (12,000/ha) and harvesting usually on a 3 year cycle. The crop is perennial, the rootstock or stools retained in the ground after harvest with new shoots appearing the following spring. The expected life of an SRC willow plantation –before stool replacement is required in around 20 years, allowing 6 or 7 crops off the initial planting. The durability of the root stock is critical to the economic success of a SRC willow venture as the initial establishment costs are high due to the very high planting stockings and intensity of the establishment regime.

Most of the willow varieties used for SRC internationally are osier willows bred specifically to ensure high yields (Figure 7), resistance to rust (the main disease of willow) and a growth habit which allows ease of harvesting. The parental stock of many of the varieties is *Salix viminalis*, the basket willow. Based off trial results; *Salix viminalis* 'Gigantea', *S. purpurea* 'Irette' and 'Booth', and *Salix schwerinii* 'Kinuyanagi' are favoured as the most suitable SRC clones currently available in New Zealand.

2.1. Site and Soil Considerations for SRC Willow Crops

2.1.1. Scale and Orientation

As a perennial crop, SRC willow is grown over a three-year cycle and grows to 7 - 8 m high by harvest. From a management perspective, sites should be at least 5 ha in size, preferably 10 ha or more. The paddock shape should ideally be square or rectangular, but as this is rarely the case, paddocks that minimize the need for short row lengths or require minimal changes in direction when planting should be chosen.

Planting paddocks that can be harvested economically is of critical importance. The slope should ideally be 7° or less, definitely no more than 15°, to ensure safe conditions at harvest. Any areas prone to uneven soil moisture availability will show depressed crop growth, just as pasture does. Appropriate access will be required for all machinery involved in establishing and harvesting the crop, e.g. gate widths should be at least 4 m, as the harvesters could be 3.5 m wide. Weight and height restrictions on any bridges that must be negotiated should be checked, not only for farm machinery but also for the high-sided vehicles used for the collection of the harvested material. Overhead wire clearance should be at least **10 m** above ground.

2.1.2. Site Selection

Willows grow best on good agricultural soils, but can be grown successfully on soils that are marginal for traditional crops (Table 1). Generally, better quality soil will produce greater yields earlier in the rotation. The best willow growth occurs on sites where the soil provides a large root volume and good aeration, water, and nutrient availability. It is recommendad that soil pH should be between **5.5** and 8.0. Willow has been grown successfully on soils ranging in texture from sandy loam to silt or clay loams.

Table 1. Soil characteristics that are suitable for growing willow biomass crops (based on internation al studies)

Soil Characteristic	Suitable	Unsuitable
Texture	Loams, sandy loams, loamy sands, clay loams and silt loams	Coarse sand, clay soils
Structure	Well developed to single grain structure	Massive or lacking structure
Drainage	Imperfectly to moderately well drained	Excessively well or very poorly drained
pH	5.5 to 8.0	Below **5.5**, above 8.0
Depth	40 cm or more	Less than 40 cm

Willow SRC can tolerate flooding but not being permanently waterlogged. Annual rainfall of 1200 to 2500 mm will provide ideal water availability; sites with annual rainfall below 1200 mm per year may lead to poor growth due to insufficient moisture. More specifically, average summer and autumn rainfall of greater than 100 mm per month is recommended. Willow grown on sites with low summer rainfall and low soil water storage would require irrigation to achieve economic yields.

2.1.3. Land Preparation

Proper land preparation for SRC is essential. As SRC willow is a long-term, perennial crop, ensuring the best soil conditions at planting will reap benefits for establishment and for all subsequent harvests. Good soil moisture within the plantation is critical for successful establishment of the willow cuttings.

Several key outcomes are required from land preparation. These include:

- Weed control
- Soil aeration
- Soil density or compaction being addressed by deep cultivation
- Fertility.

Ensuring that soil preparation for planting is carried out effectively is ESSENTIAL – it has a direct impact on how well the SRC establishes, the overall financial cost of establishment, the yield at first harvest and therefore the income from the harvested crop.

2.1.4. Weed Control

Of all operations, effective weed control is most critical for the successful establishment of willow biomass plantings. Weed competition is the most common cause of failure for willow biomass crops. Weeds compete with the cuttings for moisture, nutrients and light; and must be eliminated.

Thorough control of perennial weeds is important before planting (Figure 8). Usually a single application of glyphosate will suffice, though where there are persistent weeds like kikuyu two applications that require some three months of separation will required. Local advice should be sought around weed control

Figure 4: Pre-cultivation knockdown spray using glyphosate

Willows do not compete well with weeds during the establishment year, or during the first part of the second growing season. Once trees close canopy, completely occupying and shading the site, weeds are less able to compete. If weeds are not controlled until the trees fully occupy the site, production will be much lower during the first rotation, or in the worst case scenario, the planting may have low survival and plantation viability will be compromised.

It is much cheaper and easier to eradicate invasive perennial weeds such as couch, dock and thistles prior to planting than to try to control them once the crop is growing.

Key chemicals used over the top of established SRC willow include:

- Grass control - haloxyfop [eg Gallant ™]
- Broadleaf control – clopyralid [eg Versatil ™].

These should be used where weeds and grasses threaten to compete with SRC willows. Spring application following harvest is preferred.

Pre-emergent

Some experts recommend the use of pre-emergent sprays to control spring development of weeds following establishment. Pre-emergent sprays were not very effective on the light volcanic pumice soils in Taupo, but these chemicals, designed to provide a pre-emergent weed cap, are likely to be more effective on other soil types.

2.1.5. Cultivation

Willow cuttings planted into cultivated soil have a much greater rate of survival and establishment. Planting willow cuttings into cultivated soil is much faster, cheaper and less damaging to the cuttings than planting into non-cultivated soil. This is particularly so if mechanical planting is to be employed. Willow cuttings will grow if planted in uncultivated soil, but growth rate is significantly reduced.

As the cuttings are planted to a depth of 20 cm, it is vital that the whole of this soil profile is well structured and the soil particles of a size that allows moisture retention. Ripping or ploughing to the appropriate depth and weed control are the vital basics of land preparation.

In light Taupo soils, a two-disc operation has been effective, with the first disc using giant discs of 30 cm. The second disc uses lighter 25 cm discs that create a finer tilth for planting (Figures 5 & 6).

In heavier clay soils, ripping followed by disc and power harrowing is recommended.

Figure 5: Before cultivation

Figure 6: After Cultivation

2.1.6. Fertility

Willows grow rapidly, and respond to fertility levels, although the understanding of willow fertility requirements in New Zealand is rudimentary. In New Zealand, willow crops have grown effectively on land converted from pasture, with no further fertiliser over a period of 4 years. While willows grow in poorer soils, responses to fertiliser application have been observed here and commented on internationally. It is recommended that soil analysis before planting/cultivation be used as a basis for fertiliser management.

Soils that have not been fertilised for some years should be assessed for the following soil factors (Table 2).

Table 2: Suggested minimum values for some key soil chemicals when growing SRC willow

	Key level to trigger remedial action
Olsen P	20 mg/litre
Boron	Less than 1 mg/kg
pH	Less than pH 5.5
Potassium	Less than 0.5 me/100 g
Magnesium	Less than 1 me/100 g

Accurate nutrient requirements of SRC willow for New Zealand conditions are still under research. Willow plots treated with dairy shed effluent grew several times more biomass than untreated control plots (McIvor I, Reuse of farm dairy effluent, HortResearch, www.maf.govt.nz/sff). The extra water produced much of this gain. However, overseas sewage sludge has been used as a fertiliser to increase willow crop yields. The benefits are in slow release of low levels of nutrients, greater soil water storage, and increased soil microbial activity.

General practice is not to fertilise with mineral fertiliser during the establishment year. This is because the cuttings take time to develop roots and fertiliser is likely to be leached before it can be captured by the willow. Willow SRC has a low demand for nitrogen (N) and the current recommendation is to apply 100kg N/ha/y in the first year after cutback (**cutting first season's growth back**) and the successive harvest cycle. Where the soil has high residual N levels from previous cropping or a high soil organic matter level, these rates should be reviewed and possibly reduced.

Do not apply fertiliser during the establishment year, i.e. after cutting planting and before cutback. The root system will not have fully developed and will not be able to utilise the additional nutrients.

2.2. Planting Willow Cuttings

2.2.1. Planting design

The planting design for each paddock should be carefully thought out before planting begins. Rows should be as long as possible. Where possible, the rows should run across slopes, as with conventional crops, to reduce soil erosion and capture surface water runoff. At least 6 m should be left at row ends to allow turn-around space for harvesting machines and for access with other farm equipment.

Overseas experience shows that straight lines are preferred. Lines that bend make mechanical weed control and harvesting imprecise and difficult.

Once established, willow biomass crops will be productive for about 20 years, so mistakes in the planting design could cause problems for many years.

Thorough planting preparation is essential – it has a direct impact on how well the SRC willow establishes, the overall financial cost of establishment, the yield at first harvest and therefore the income from the harvested crop.

2.2.2. Planting material

Willow planting material consists of unrooted dormant stem cuttings 25 - 30 cm in length and 8 - 30 mm in diameter.

Willow cuttings are stored at 2^o - 5^oC, and transported to the planting site just before they are to be planted. Once cuttings are delivered, they should be planted as quickly as possible, and not be re-chilled. During planting, cuttings should be stored in conditions as cool and moist as possible. Under cool moist conditions they can be maintained outside the chiller for approximately one week, provided they are in their original containers, are not overheated, and do not dry out. Willow cuttings should never be stored in direct sunlight or under conditions that promote drying.

The cuttings are planted with 2-3 cm only above ground. Cuttings will produce both roots and shoots after planting. The original cutting, the shoots and the roots together, form a unit called a stool.

2.2.3. Timing of planting

Willow planting can be done in late winter to early spring. In NZ , planting should take place in July to September when soil moisture is high and coinciding with normal willow budburst. Planting should take place several weeks before expected budbreak.

Shoots sprout one to two weeks after planting under typical New Zealand spring conditions, and this can occur as quickly as 3 days after planting if soil and air temperatures are suitable.

There is little advantage to planting earlier because low soil and air temperatures typically result in slow sprouting and growth, and early planting increases the chance of frost damage to young, newly sprouted cuttings. Willows grow best with warm temperatures and moist, but not saturated, soils.

2.2.4. Planting densities

Willow cuttings are planted at densities of about 12,000 per hectare. Planting can be mechanised with equipment specifically designed for dormant hardwood cuttings. It is expected that large-scale planting in New Zealand would be mechanised. To facilitate harvesting, willows are planted in a double-row system with 1.5 m between double-rows, 0.9 m between rows, and 0.7 m between plants within rows (Figure 7).

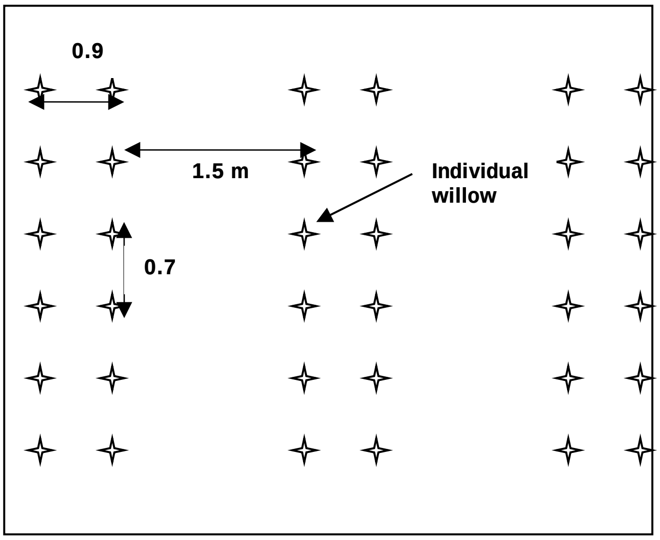

Figure 7: Willow cuttings are planted in double rows 1.5 m apart. The spacings shown in the diagram will give a density of around 12,000 stools/ha.

2.2.5. Planting Machinery

The two most common examples of planting machines are the Edegal planter and Salix Maskiner's Step™ planter (Figure 8), both of which were designed and produced in Sweden.

Figure 8: Step Planter

The planter opens a slit in the ground to a depth of 20 - 25 cm. Cuttings are fed manually into the planting tube and are driven into the open slit by hydraulically powered rubber wheels. A pair of packing wheels closes the slit around the cutting. Planting machines are capable of planting over 1 ha per hour.

3. MANAGEMENT

3.1. The first growing season

Depending on time of planting in relation to the advent of the growing season, cuttings sprout shoots within two weeks of planting. Roots are being produced underground at the same time. Typically 90% or more of the cuttings survive. If cutting survival is only around 60-70%, advice should be sought about whether to replace the dead cuttings or replant entirely.

If survival and weed control are acceptable during the first growing season, no further effort is required until leaf fall. If the pre-emergence herbicide cap fails and annual weed seeds germinate, or if perennial weeds not killed during site preparation begin to compete with trees, mechanical cultivation or chemical control will be necessary. Annual weeds are generally easily controlled mechanically when they are small (English practice). This has not been practised in New Zealand. If perennial weeds become established, several weed cultivations may be necessary. Contact herbicide application with shielded sprayers has been used successfully, but willows are highly sensitive to several post-emergent herbicides, so the risk of damaging trees is high.

Willows are highly sensitive to several post-emergent herbicides. Haloxyfop and clopyralid have proven to be effective in controlling weeds without damage to willow. Get technical advice on which herbicide to use when.

Growth during the first growing season (Figure 9) varies by clone/species, rainfall, and site conditions.

Figure 9: First year growth

Stools should have one to four stems from 1 - 2 m tall by the end of the first growing season. At the end of the first growing season and after leaf fall (typically mid May), stools are cut back (coppiced) to 10 cm above ground level to encourage the development of the multi-stemmed coppice. This operation could be completed any time between two weeks after leaf fall and when buds begin to swell in spring (typically during August).

Cutback means cutting down the stool to 10 cm above ground level after the first growing season to produce multi-stemmed growth. It is the first coppice activity.

Cutback can be completed with a sickle bar mower equipped with sharp blades so that a clean cut is produced. The forward speed of the tractor should be such that stems are being cut cleanly, without tearing, and the willow's root system is not being ripped from the soil. Any machine that pulls up on the plant before cutting would not be suitable, since the plant's root system would be damaged. Cut stems can be left in the field, or made into cuttings if additional planting material is desired. Cutback promotes multiple sprout formation and results in rapid canopy closure the second year.

Figure 10: Cut back in trial using a brush cutter

Cutback not only encourages the multiplication of stems on the stool, but also increases the root biomass and number of feeder roots. Root biomass increased by over 100% in the growing season following cutback, compared with stools not cut back.

Cut back willows during a spell of fine weather to reduce the chance of fungal spores infecting the cut surface.

3.2. Second through fourth growing seasons

3.2.1. Fertility

After the willows resume growth during the second season, and assuming weeds are under control, apply nitrogen fertiliser at about 100 kg of elemental nitrogen per hectare. Potassium or phosphorous addition may be needed on some sites. Rates may vary depending on the fertility of specific sites. Timing of fertiliser application depends on the growth rate of the plants. Machinery must not damage the plants as it passes over them, but young willow stems can be bent over without damage provided the object causing the bend (e.g., a tractor axle) pushes on the top third of the stem.

Ideally, fertiliser application would be during November so that trees are vigorously growing and have had a chance to produce new roots that can absorb the fertiliser. Experiments overseas have shown that a wide range of organic wastes, including sewage biosolids and composted poultry manure, can be used to supply nutrients. These organic amendments are ideal for slow release of nutrients over the three- to four-year growing cycle. Weed control may be necessary during the first part of the second growing season, until trees close canopy. If weeds become established during the second season, they should be removed prior to fertilisation; otherwise, fertilised weeds may overtop trees.

Apply weed control BEFORE fertilising the coppiced willow crop

Willows should close canopy (Figure 11) by mid to late November of the second growing season.

Figure 11: Trees generally close canopy by the second growing season, effectively suppressing competing vegetation.

Each willow plant should be 2 - 3 m or more in height by the end of the second growing season and have multiple stems (Figure 12).

Figure 12: Stem development following coppice

Figure 13: Crop ready to harvest

Once the canopy is closed, weeds will be suppressed and no further weed control efforts are necessary until after harvesting. [During the third and fourth growing seasons (second and third seasons after coppicing), no tending of the crop should be necessary. Plants should be 5 - 6 m in height by the end of the third season and up to 7 - 8 m by the end of the fourth season (Figure 13).

The third, and particularly the fourth growing seasons are when the above-ground growth is expected to be most rapid.

3.2.2. Crop Yields

Yields will depend on management, e.g. planting density, stool survival, weed control, and on climatic and soil conditions, e.g. annual and summer rainfall, frost frequency, soil water storage.

In New Zealand, yields have ranged as high as 23 odt/ha/annum for a single 3rd year. Low end figures of 7.3 odt/ha/annum have also occurred. Mean yields over 3 years are more likely to be 14 to 16 / odt/ha/annum, with much of the variation driven by rainfall /droughts. The yield (16 odt/ha/annum) used in this study to determine economic returns was based on actual yield in the Taupo region from the average of three growing seasons. The region experienced two droughts during this period.

Breeding programmes should continue to produce varieties that increase current yields. Efforts by Salix Limited are underway in New Zealand to improve the yields and form of willow biomass crops. In addition, yields will be increased by optimising various inputs of the production system, such as weed control and fertilisation.

Figure 14: In the second coppice cycle, these willows are one-year-old above ground on a four-year-old root system.

3.3. Harvest of Short Rotation Willows

In typical (non-irrigated) crops willows should be ready for their first harvest three years after the first cutback. If growth is poor due to weather conditions such as drought or problems with weed competition, it may be sensible to delay harvesting for another year.

Where willow crops are irrigated by waste water then shorter coppice rotation may be required. It is likely that 2 year cycles will prevail.

Subsequent harvests will occur every three years. The stools are expected to complete six or seven harvests before replacement is necessary.

3.3.1. Harvest Machinery

Forage harvest machinery has been used overseas to harvest coppice willow. Harvesting equipment has been developed in Europe specifically for willow biomass plantations. The most efficient machines currently are the modified Claas Jaguar HS-2, similar to a corn harvester (Figure 15) and the Bender harvester. The Claas harvester has two large saw blades, one for each row in a double row that cut the stems at approximately 7.5 to 15 cm above the ground. Both harvesters chip the stems after cutting them (Figure 16) and blow the chips into a bin-trailer towed by the harvester or by a tractor beside the harvester. Other willow harvesters have been developed in Europe that bundle whole stems, rather than chip them. Advantages of chipping include less handling and more efficient transport. Whole stems can be stored longer than chips, but add to the cost of transport and handling.

Figure 15: Jaguar HS-2 harvest machine being serviced in preparation for harvesting

Wider tyres or tracks on harvesting machines minimise soil damage when harvesting in wet conditions. Willow harvesting machine improvements continue overseas; and current harvest rates are from 30 to 50 OD tonnes per hour, or approximately 0.5 to 1 hectares per hour. Currently there are no commercial willow harvesting operations in New Zealand.

Willows sprout vigorously in the spring following harvest, and harvesting can be repeated on a three to four-year cycle as discussed above. It is expected that six to seven harvests can be obtained from a single planting before replanting. The fact that multiple harvests can be obtained from one planting with only a minimal amount of work once the crop is established is an attractive feature for the grower.

Figure 16: Harvest machine in operation in Europe

3.3.2. Timing of Harvest

In New Zealand, harvest should be focused on autumn and winter (May to August), with a secondary option towards the end of summer (March). Ground conditions in specific regions at different times of the year will determine the harvest window. Harvesting will be difficult in poorly draining soils in winter. This may be a limiting factor for energy farming in places such as Northland and Southland where heavy clay sopils are prevalent, or at least a limiting factor on when to harvest.

While there is evidence that productivity increases from year two to three through increased basal area (see Figure 17), farmers may choose to harvest in years one and two. Early harvest will reduce overall productivity, incur increases in cost and may reduce the lifetime of a crop of stools. Yet early harvest must be considered to accommodate larger stem diameter (as occurs with *S. schwerinii*) and has few operational limiting factors.

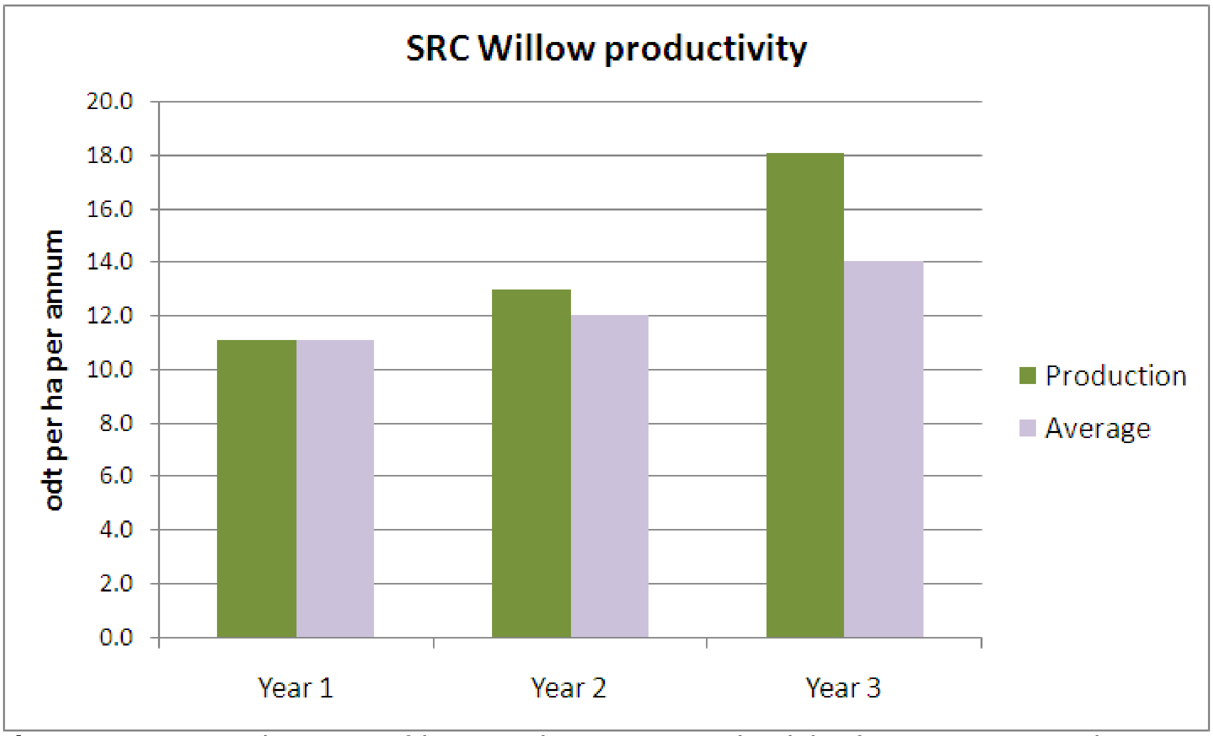

Figure 17: Expected pattern of increase in average productivity from year one to three.

Note: Production increases in years 2 and 3 improve the average production over a 3-year cycle.

3.3.3. Constraints

One critical constraint for timing of harvest in New Zealand is paddock access, although the free draining soils of the Central North Island should allow harvesting to proceed at most times of the year.

Stem size may be the constraint determining the choice of harvester. Harvesters such as the dedicated Claus Jaguar 850 HS-2 harvest machine are capable of harvesting stem size of 100 mm, although the operational preference is below 65 mm. *Salix schweirinii* (kinuyanagi) stems can reach this size, while other clones are unlikely to exceed 60 mm. Where kinuyanagi is being cropped, the Claus HS-2 is recommended as being a particularly robust harvester. Harvest machinery is most constrained by the ability to chip larger stems – not the cutting of the stem.

Land contour may also be a constraint. Given the easy contour of land in Sweden & the United Kingdom where SRC willow has been eastablished, there is little experience of limits imposed by contour on their harvester specifications. New Zealand SRC plantings should follow the Claus Jaguar constraints on contour limitations.

Harvest of 50 OD tonnes per hour is possible where biomass is present at 25 tonnes per ha (oven dry weight), and stem size averages 50 to 60 mm.

3.3.4. Productivity

Productivity of SRC increases from year one through three of the coppice cycle, largely because of increase in stem diameter. Height growth is generally complete by year 2. This means that optimum production will be gained through longer crop rotations. Based on overseas data, this principle is depicted in Figure 18. The dark bars are the years production, the light bars are the average over that period of the coppice cycle.

4. BIOMASS PRODUCTIVITY - NEW ZEALAND

The biomass productivity of an SRC plantation is expressed in oven-dry tonnes per hectare per year (odt/ha/year). Data collected from seven countries, covering a range of clones and planting densities, indicated an average yield of 7 odt/ha/year with a range from 2.2 to 13.5 odt/ha/year. With the possible exception of Sweden, very few countries have large-scale commercial plantings of SRC and, therefore, the majority of crop yield data are derived from intensively managed, small experimental plots. Figures of up to 36 odt/ha/year have been recorded for willow growing under optimal water and nutrient conditions but these are abnormal expectations for field conditions

With new clonal material being released, improved silvicultural techniques and better pest and disease management strategies, it should be possible to achieve average yields in well managed irrigated plantations of between 12 and 18 odt/ha/year under New Zealand conditions.

Biomass was measured in a demonstration trial to the west of Lake Taupo. This site was coppiced in 2007 and biomass data (Figure 17) was collected from plots of Salix viminalis and Salix schwerinii 'kinuyanagi' in 2008, 2009 and 2010 (Table 3).

Table 3: Biomass productivity (Mean Annual Increment) from demonstration plantings after coppicing

	S. viminalis	range	*S. schwerinii*	range
	ODT/ha/yr	ODT/ha/yr	ODT/ha/yr	ODT/ha/yr
Year 1	7.8	7.2 - 8.6	11.1	8.6-12.5
Year 2	11.1	8.6 - 13.0	13.0	10.7-15.5
Year 3	17.0	15.5 - 18.4	18.1	12.7-23.6
Total	35.9	31.3 - 40.0	42.2	32.0 – 51.6
Annual Average	11.9	10.4 - 13.3	14.0	10.6 – 17.2

The productivity of the demonstration planting is considerably higher than trial plantings in a drier zone north of Taupo, although there is considerable plot to plot variation. This is possibly from the better rainfall in this area, despite there being less than normal rainfall for two of the years the coppice has been growing. The good productivity may also be a consequence of the older root systems generating the coppice. However the root age is what would be expected from a typical second rotation managed stand (Snowdon et al. 2008).

Consistently high levels of biomass production are essential if SRC is to become an effective fuel component of an energy supply system.

5. ECONOMICS OF SRC WILLOW IN NEW ZEALAND

SRC willow is proposed as a commercially viable, sustainable crop for farmers and foresters.

5.1. Costs

Table 4 sets out estimated costs for establishing a crop of SRC willow. These are per hectare costs, and are based on actual experience in New Zealand, and reassessed against costs in Sweden, England and the USA. A management surcharge of 5% is included.

Table 4: Establishment Costs

Operation	Costs	Unit	$NZ/ha (with 5% surcharge
Pre plant spray	$ 120	1	$ 126
Cultivation	$ 380	1	$ 399
Planting Stock	$ 0.15	12,000	$ 1,890
Planting	$ 0.04	12,000	$ 504
Release	$ 300	1	$ 315
Fertiliser	$ 110	1	$ 116
			$ 3,350

The cost of land is a complex subject, influenced by capital gain, ownership, contrasting land use options, sustainability issues within Taupo and Rotorua catchments, tax laws and interest rates. Within this exercise land is simply treated as a rental cost at 4% of 10,000 per hectare.

In year two, further crop management is required to maintain optimum growth. Costs, including a management surcharge of 5%, are presented in Table 5.

Table 5: Cyclical costs per crop

Operation	Costs	Unit	$NZ/ha (with 5% surcharge
Cut Back	$ 100	1	$ 105
Fertiliser	$ 107	1	$ 112
Winter Weeds	$ 120	1	$ 126
Release	$ 300	1	$ 315
			$ 658

In the season following harvest fertilizer, winter and spring weed spraying should be undertaken if conditions determine the need.

Key operational costs include harvest and transport (estimated at 50km lead distance). Expected costs, including a management surcharge of 5%, are presented in Table 6.

Table 6: Harvest Costs

Operation	($/ODT)	ODT per 3 year	$NZ/ha (with 5% surcharge
Harvest	17.0	48	857
Transport	18.0	48	907
			1764

Harvest and transport costs represent significant costs in the overall supply chain (up to 70%). Yet these charges are significantly lower than for tree based biomass systems.

5.2. Revenue

Two factors determine revenue from SRC willow. Yield is projected to be 16 oven dried matter (ODT) per ha per annum. This is considered realistic in areas with adequate summer rainfall.

Price for chipped willow will be set by the market. Industry sources (wood waste, pulp, and heat users) approached during the preparation of this handbook valued hardwood chip at $50 - $105 per ODT, depending on its quality and use.

This analysis uses $90 per ODT as a starting point (Table 7). In the foreseeable future, carbon is unlikely to add value to biomass.

Table 7: Revenue

	Revenue	ODT per 3 year		$NZ/ha
Revenue	$ 90	48	$	4,320
Maintenance			$	553
Harvest	1764		$	1,764
Total Cost			$	2,317
			$	2,003
EBIT pa			$	668

The cost of production is expressed in per ODT in Table 8.

Table 8: Cost of production

	$NZ/ODT Excluding land	$NZ/ODT Including Land
Cost	$57	$85

5.3. Markets

Peak oil and national biofuel policies provide opportunities for crops of SRC willow. New markets will develop and take shape as policy and production of renewable fuels impact on the business landscape.

The 2009 Scion report on Bioenergy Options proposes that to attain independence from oil as the prime source of transport fuel by 2050 there is a potential need for up to 1.8 million ha of biomass crops. That is, all biomass produced from 1.8 million ha of new forest would be required to meet domestic liquid fuel consumption. Put in context, NZ already has a

1.7 million ha forest resource. Clearly, more wood will be required for fuel than is consumed by NZ in timber, pulp and paper and panel products.

Growing SRC willow can assist farmers to diversify their business and target the expanding energy biomass market.

Markets for SRC willow in New Zealand include:

- Biofuels such as ethanol
- Bio-materials derived from lignin and sugars
- Heat and electricity generation
- Fodder and anthelmintics.

Several factors should be examined when considering market opportunities. Risk, scale, value and access to markets are all valid concerns when considering new opportunities (Table 9).

Table 9: Markets for SRC willow biomass

	Risk	Scale	Value	Access
Ethanol	Technology	Global	Moderate	Open via fuel mandate
Lignin	Technology	Global	High	Clear opportunity to replace oil based paints and plastics
Sugar (xylitol)	Technology	Large	High	Via food and pharmaceutical sectors Xylitol has value as a sweetener safe for diabetics
Heat and electricity	Competition from fossil resources residues & geothermal*	Moderate	Increases likely Calorific value will improve	Linked to development of cogen sites
Fodder	Low	Farm requirement	Low – except in drought years	Open

*Taupo and Rotorua both have current and potential for both geothermal heat and electricity

6. REMOVAL OF SRC WILLOW

At the end of the productive life of the SRC plantation or to replace stools with improved clones, the old stools need to be killed off preventing further growth and the root structure removed to allow soil cultivation.

One of the most effective herbicides found to kill off coppice stools is glyphosate, a translocated, foliar acting contact herbicide. This is probably the cheapest method of preventing the re-growth of coppice stools. Following harvest, the stools are allowed to re-shoot in spring until ≈150–200 mm high. Glyphosate is then applied at 6 litres product/ha using a standard tractor mounted sprayer. Trials have shown that this first application achieves a 90% kill of the stools. The site is then left during the summer and any remaining stools are killed off with a second, lower dose application of glyphosate in late summer. Depending on the initial stump size and the rate of decay, the site can be ploughed either in autumn or spring the following year.

Alternatively the stools can be grubbed out as entire stumps using a narrow bucket fitted to a digger, and removed from the site.

7. WILLOW CROP PESTS AND DISEASES

7.1. Diseases

Fungal pathogens have been observed on willows in New Zealand, but so far, fungal problems have been minimal and restricted to specific clones. A fungal rust *(Melampsora spp.)* is the most serious disease in New Zealand (Figure 18), causing premature foliage drop. *Melampsora epitea* seriously affects the shrub willows *S. cinerea* and *S.* x *calodendron,* and to a lesser extent *S.* x *reichardtii.* An unidentified *Melampsora* species has been observed attacking various clones of *S. viminalis*. Planting clones resistant to pathogens is the best method for managing diseases. One of the criteria for breeding programmes is selection based on resistance to known pathogens, including fungal rust. However, pathogens can mutate and new pathogens can arrive in the country.

Figure 18: Rust on tree willow leaf – no impact on SRC willow

Silverleaf is the most serious disease in New Zealand willow stool-bed nurseries and is caused by the fungus *Chondrostereum purpureum*. This pathogen has an extremely wide host range, attacking all willow cultivars. It is spread by airborne spores which enter fresh cuts (usually less than one month old) establishing infection. Spores are released with the combination of rainfall and high relative humidity (>95%). Most infection is in spring, but decreases through summer and autumn and is seldom in winter.

The infection causes a production of a toxin in the wound which is translocated to the foliage during the growing season causing silverleaf, leaf curling, wilting, reducing leaf size and retarded growth. Dieback follows in late summer or early autumn. Fungicide application to the cut surfaces may be needed following coppicing if silverleaf infection is observed. In Sweden bacterial damage from *Pseudomonas syringae* in association with freezing stress has led to stem dieback in SRC willow plantations. It is not known if this will be a problem in New Zealand.

7.2. Pests

Insects generally have not been a problem in osier willow plantings in New Zealand. *Pontania proxima* (willow leaf gallfly) causes small dark red or yellowish galls to form in the leaves. Although unsightly, these galls have little effect on growth or vigour. Of greater concern is the willow sawfly (*Nematus oligospilus*) (Figure 19) which can defoliate and kill willow trees. To date, serious damage has only been done to tree willows while osier willows have been less seriously affected. Foliage of shrub and osier willows is sometimes damaged by *Eucolapsis brunnea* (bronze beetle) chewing the leaves causing a 'shothole' effect. The brown beetle *Costelytra zelandica* (grass grub beetle) damages the leaves by chewing from the edge into the mid-vein, often leaving the midrib only. Spraying with insecticide should not be needed.

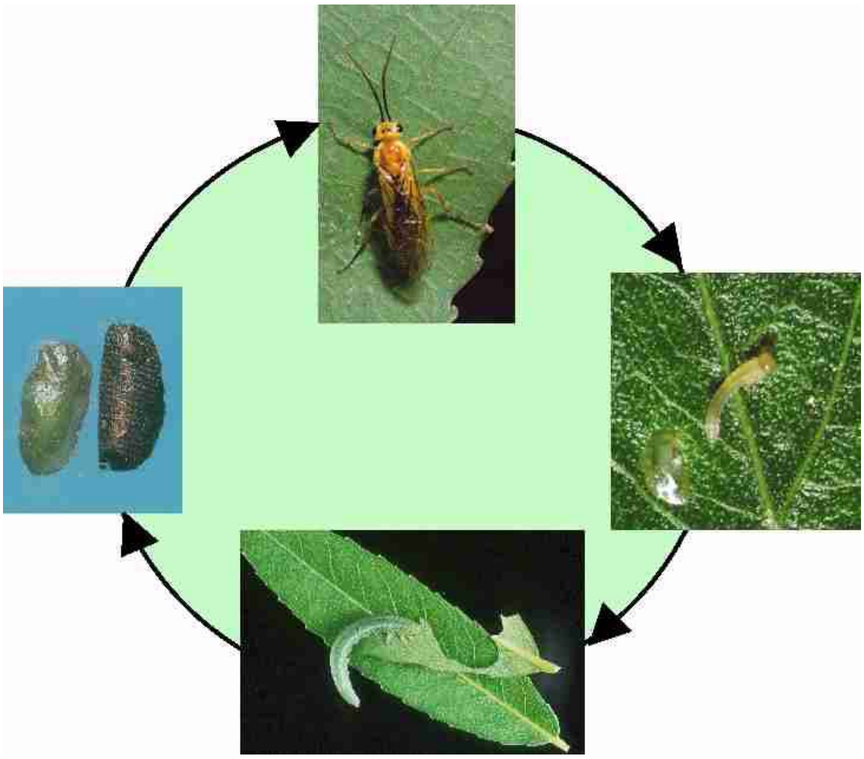

Figure 19: Life Cycle of willow sawfly

7.3. Animal Pests

Browsing damage by rabbits, hares, deer and possums can kill sprouting cuttings in the establishment year or after cut-back or harvesting. These pests should be intensively controlled.

8. BIOENERGY OPTIONS IN WATER CATCHMENT MANAGEMENT

In the Central North Island two lake catchments (Taupo (Figure 20) and Rotorua) are stressed by increased productivity from farming and other human activity. Each has been the subject of scientific evaluation of the role of nutrients on the ecology of lakes and streams. In each case different rules and systems have been imposed to drive land use change that should restore lake water quality in the medium to long term (80 to 200 years) to predetermined levels.

Figure 20: Lake Taupo – looking south to Mount Ruapehu

Because of their potential to provide low nutrient emitting yet commercially viable land use short rotation crops are a potential solution for helping to protect lake catchments. With nutrient emissions similar to that of indigenous forest, short rotation crops can address the use of better quality land in these catchments. The challenge is to identify higher value markets for biomass balanced with the scale of markets to make a difference.

Short Rotation crops also have potential to assist in the treatment of waste water. Rather than pursuing highly engineered solutions that are likely to be highly expensive, some councils are considering the use of short rotation crops in treating waste water.

SRC willow provides opportunity for waste water to be treated with uptake of nitrogen (and potentially phosphate) a key outcome in the protection of aquifers, waterways and catchment wide systems. The use of subsurface drip irrigation is likely to be beneficial. Firstly, subsurface drip irrigation reduces the infection levels of disease in the willow crop, while it also reduces the impact of ponding, aerosols, wind drift, and rainfall runoff cross contamination caused by spray irrigation systems. Subsurface irrigation provides a slower, more measured release of water and nutrients into the root zone of SRC willow. Proven sub-surface irrigation technologies that deliver to the root zone and protect against root intrusion and bacterial slime are available

Another application of short rotation crops is treatment of effluent from dairy sheds. Waikato Regional Council (personal communication) estimates this could address 11% of dairy farm waste from a point source that is therefore controllable and able to be treated. A study undertaken by Plant and Food Research in Wairarapa [i]demonstrated that up to 400kg N /ha/ annum could be taken up by short rotation willow and poplar crops from treated dairy effluent.

8.1. Taupo Case Study

Intentions to grow short rotation willow crops in NZ were driven by the need for large scale, sustainable land use in Taupo catchment. Leaching of urine patches from cattle is the primary driver of nitrification that threatens the pristine nature of Lake Taupo.

Following promising early trials of SRC willow in 2004, a large scale science based trial was established in 2005 (Figures 21 and 22). This was actively supported by Sustainable Farming Fund, Waikato Regional Council, and Maori land owners.

Figure 21: Rotokawa trial 2005

2007 saw the establishment of two key businesses:

- BioJoule Ltd to develop and deploy disruptive technology for fuel and bio-polymer
- Salix Ltd to develop a large scale nursery to drive SRC crops

By 2008 climate change was a key driver towards biomass crops, with SRC willow acknowledged as having good growth potential, low pests, and some certainty for positive cashflows. More than one market was identified.

8.1.1. Current Status

Trials have proven that SRC willow can be grown in Taupo and a nursery has been established to enable crops to be established. Several markets have been identified including fuel, biomaterials, and heat energy.

Skills and knowledge developed in Taupo can be applied here and to other regions so that farmers diversify into the energy market, maintain commercial viability, and improve sustainability.

Economies are adapting to the threat posed by climate change, while preparing for the end of oil as cheap, easily available energy. SRC willow provides NZ with an option to grow its own energy. Its farmers have the land and skills to succeed.

Figure 22: Up to 4 meter regrowth in one season

8.2. Case Study - Birds New Zealand willow coppice

Excerpt from Ringers' Bulletin; Summer 2008 - Danielle Fry & Fred Slater

Denise Wawman's recent account in Ringers' Bulletin of Bird Banding Down Under prompted us to share our experiences of bird ringing in short-rotation willow coppice (SRC) near Taupo in North Island, New Zealand. Danielle is coming to the end of a study of birds utilising short-rotation willow coppice in Wales.

SRC is one of the options for renewable energy in the UK and a wonderful crop for biodiversity, particularly bird species. While we were in New Zealand in August 2006, we took the opportunity to compare our Welsh SRC sites with a similar site amongst the volcanic steam of central North Island. August in and around Taupo brought frost, fog and snow, reminding us of our winter mist-netting in mid-Wales. But it was not just the weather that made us feel at home; most of the birds and the field weeds were the same as we find in the UK.

Figure 24. Silvereye in Taupo

One of the important features of early rotation willow coppice in Wales is the value of the arable weeds, particularly in the first winter, to finches and other small passerines. Over much of inland Wales, arable land mixed with pasture is a thing of the past; pasture alone is now more common, but provides few winter seeds.

The view from our first-year willow site near Taupo was of pastureland backed by conifer plantations. Apart from the plumes of vented steam, this is not dissimilar to many a Welsh landscape. As our first job, we collected data from pastureland vegetation quadrats, in order to roughly quantify the seed resource available to the birds. Table 1shows the species that we found; even nonbotanists will recognise some of them.

Figure 25 Fantail

Having established what food was present, we set up our mist nets (with banding permit and rings from the New Zealand Department of Conservation) and waited for the birds, with identification books to hand. We need not have worried. Most of the species were much the same as we would expect at home Table 10), with Redpoll sp, Chaffinch, House Sparrow, Yellowhammer, Greenfinch and Dunnock making up the majority of the birds on the list, although Silvereyes were the second most abundant species. Fantails, although less frequently caught, also followed us around, avoiding the net with deliberate ease.

Our time mist-netting in the SRC of New Zealand made us aware that it doesn't matter where you grow this crop; provided that the mix of small passerines is similar, the way these birds utilise the crop appears to be universal, and the value of SRC to birds will apply wherever it is grown.

Table 10 Grass Species in SRC

Common Name	**Scientific Name**
Common Sorrel	*Rumex acetosa*
Creeping Bent	*Agrostis stolonifera*
Italian Rye-grass	*Lolium multiflorum*
Yorkshire Fog	*Holcus lanatus*
Dandelion	*Taraxacum (agg)*
Cocksfoot	*Dactylis glomerata*
Common Chickweed	*Stellaria media*
Mouse Ear	*Cerastium fontanum*

Bird's-foot Trefoil	*Lotus corniculatus*
Meadow Grass	*Poa annua*
White Clover	*Trifolium repens*
Bloody Crane's-bill	*Geranium sanguineum*
Mullein	*Verbascum sp*
Nightshade	*Solanum sp*
Timothy	*Phleum pratense*
Orache	*Atriplex sp*
Liverwort	*Marchantia sp*
Common Catsear	*Hypochaeris radicata*
Sowthistle	*Sonchus sp*
Red Fescue	*Festuca rubra*
Bog Stitchwort	*Stellaria alsine*
Parsley-piert	*Aphanes sp*
6 occasional non-UK species	

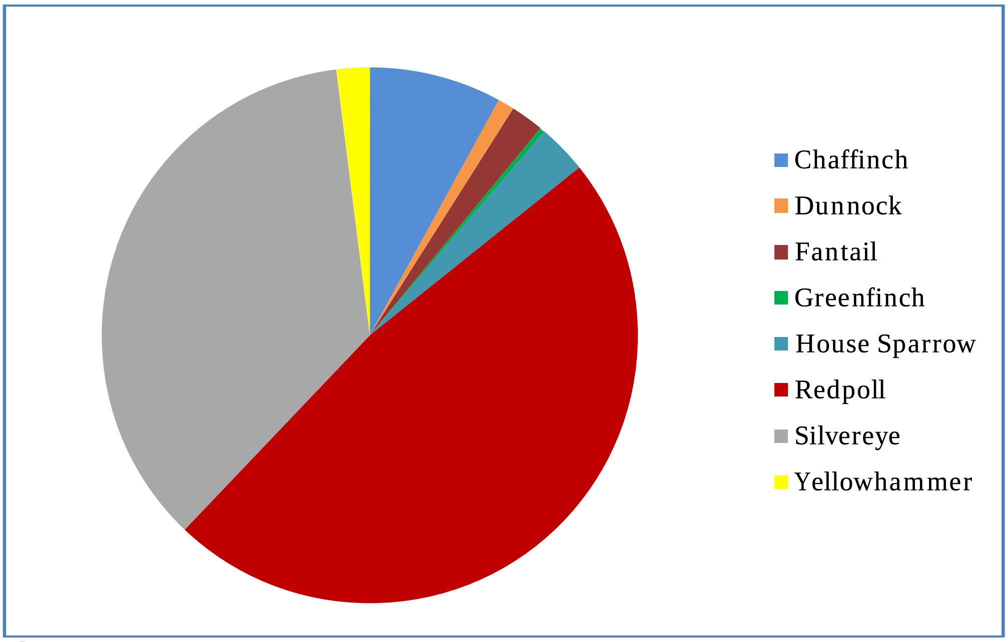

Figure 26: Bird Species Caught in Taupo coppice

9. CONCLUSIONS

SRC willow may be useful land use option for landowners / farmers in New Zealand.

Systems for establishment and management of SRC willow are well understood, documented and practiced. These can be implemented in New Zealand – modified with consideration for the local climate and other conditions and based on learnings from NZ trials.

Drivers for development for SRC willow are likely to be;

- Need for land use change in distressed lake catchments with SRC willow offering a crop option that reduces Nutrient leaching

- Longer term need for biomass to meet the demand for production of liquid fuels, substituting for fossil derived fuels and chemicals.

Species that show promise are; ***Salix viminalis*** **'Gigantea', *S. purpurea* 'Irette' & 'Booth', and *Salix schwerinii* 'Kinuyanagi'**

Pests and diseases are not expected to be significantly limiting factors to production from the preferred species trialed in New Zealand, but will need to monitored and managed

Likely productivity is in the range of 14 to 16 odt per ha per annum, with a total volume at harvest of 42 to 48 odt per ha.

Biomass produced from these systems is estimated to cost;

- $NZ 57 per ODT excluding land
- $NZ 85 per ODT including cost of land

SRC willow cannot be successfully managed and harvested on and from hill country with slopes of over 15^o. However, on sites where it can be grown the costs are lower to those of more conventional tree based systems on a per oven dry tonne basis.

10. GLOSSARY

Bio-ploymer: Polymers derived from natural sources

Breeding: Intensive selection and subsequent mating of top selections to achieve cumulative genetic gain over time.

Cellulose: The main constituent of the cell walls of plants.

Coppice: Re-growth of some trees after pruning or cutting back.

Clone: A group of genetically identical plants, which have been vegetatively propagated from a single individual.

Cutback: Coppice cut after first years growth to improve vigour and stem numbers.

E10: 10% ethanol mix with 90% petrol used to fuel transport

EBIT: Earnings before interest and tax.

Ethanol: The main biofuel replacement for petrol. It is produced by fermentation of sugars.

Gigajoules: A gigajoule (GJ) is a metric term used for measuring energy use. For example, 1 GJ is equivalent to the amount of energy available from either:

- 277.8 kWh of electricity, or
- 26.1 m3 of natural gas, or
- 25.8 litres of heating oil

Hardwood: Wood from a broad-leaved tree as opposed to from a conifer.

Hemicellulose: Contain many different sugar compounds, making it a random, amorphous structure with little strength.

Hybrid: The offspring of parents that have distinct genetic differences. Can apply to the progeny from matings within species (intraspecific) as to those between species (interspecific). Hybrids combine the characteristics of the parents or exhibit new ones.

IRR (Internal Rate of Return): The discount rate that equates the various costs and benefits anticipated in future years of forestry (or other) operations.

Lignocellulosic: Woody plants are lignocellulosic with cellulose, hemicellulose and lignin.

PetaJoules: 10^{15} joules of energy. Electricity: 1 million kWh = 3.6 terajoule (TJ), or 1 petajoule = 1000/3.6 = 277.77 million kWh.

Short Rotation Coppice (SRC): the commercial utilisation of woody crops such as willows, poplars, Robinia and Eucalyptus with coppicing abilities.

Stool: A plant grown in a nursery bed, which has been hedged or topped to produce adventitious shoots, which are subsequently used for vegetative propagation.

Tissue culture: (syn. micropropagation) Growing plantlets from small pieces of plant material on artificial media in a sterile, laboratory environment.

Tree improvement: Usually synonymous with tree breeding, but may also refer to breeding in combination with cultural practices, particularly propagation.

Vegetative propagation: (syn. vegetative multiplication) Multiplication of plants via asexual means, i.e. without sexual reproduction. Includes tissue culture, rooted cuttings, and grafting.

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TRIBUTE - Ian Nicholas

During the preparation of the SRC Handbook for New Zealand, Ian Nicholas passed away. Ian was a key driver of research and development on Short Rotation Crops in New Zealand, providing scientific rigour, links to skills and insights from the global SRC fraternity. His passion to establish new biomass crops, his ability to relate to a wide circle of people, and his determination to support and liase with others is acknowledged.

Ian fought and lost a battle with cancer. New Zealand lost a staunch and valued forest scientist and forester. Many of us lost a friend.

IEA Bioenergy

IEA Bioenergy is an international collaboration set up in 1978 by the IEA to improve international co-operation and information exchange between national RD&D bioenergy programmes. IEA Bioenergy's vision is to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use. Currently IEA Bioenergy has 22 Members and is operating on the basis of 13 Tasks covering all aspects of the bioenergy chain, from resource to the supply of energy services to the consumer.

IEA Bioenergy Task 43 – Biomass Feedstock for Energy Markets – seeks to promote sound bioenergy development that is driven by well-informed decisions in business, governments and elsewhere. This will be achieved by providing to relevant actors timely and topical analyses, syntheses and conclusions on all fields related to biomass feedstock, including biomass markets and the socioeconomic and environmental consequences of feedstock production. Task 43 currently (Jan 2011) has 14 participating countries: Australia, Canada, Denmark, European Commission - Joint Research Centre, Finland, Germany, Ireland, Italy, Netherlands, New Zealand, Norway, Sweden, UK, USA.

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