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Short Rotation Forestry

The interface between agricultural production and conventional forestry

Figure 1: One of the Eucalyptus nitens plots at the Johnstown castle field trial in 2017.

WHAT IS SHORT ROTATION FORESTRY?

The growth of short rotation woody crops for fibre and energy uses has a long tradition. The current concept of close-spaced, fast growing (1 to 15-year rotations) silviculture evolved scientifically via tree breeding programs in the early 20th century. While short rotation coppice is a system based on cutting back trees to a stool to produce multiple stem regrowth, which is typically harvested on rotations of 2 to 4 years (e.g. willow and poplar systems), short rotation forestry (SRF) is a form of forest management designed to maximise woody biomass production on single stems over rotation lengths much shorter than the 40+ years of conventional forestry. The aim is to harness the high productivity rates of young plantations but with a higher wood-to-bark ratio than coppiced material. Plantations are harvested when annual growth rates no longer exceed mean annual increment.

Demand for wood biomass is increasing globally as concerns about the environmental impacts of fossil fuel use and of carbon-intensive, non-renewable materials continue growing. SRF has the potential to contribute to meeting this global demand for wood biomass while helping to reduce pressure on natural forests and providing an alternative income for rural communities. Demand for wood biomass for energy is increasingly seen as another market competing with other existing forest products as global efforts to reduce greenhouse emissions intensify. An increase in the use of wood biomass to meet renewable energy targets is expected and this will increase the competition between assortments used for wood fuel and fibre, thus an increase in the price of these assortments. SRF also has the potential to produce cross laminated timber products, contributing to such markets routinely in Brazil and Australia. As a highly productive system, it is often combined with biosolid and waste water management or in decontamination of flood plains. Such ecosystem services can contribute to the fertility requirement of sustained high yield production, providing further drivers for a business model centred on the production of biomass feedstock.

IRISH EXPERIENCE

The objective of the Irish "Forestry for Fibre" scheme is to address a forecasted shortfall in the supply of fibre for the energy and wood products sectors by incentivising the establishment of Italian alder, hybrid aspen, poplar, and eucalyptus plantations. To date there has been little take-up. ShortFor (2013 to 2018) was a recent research project funded by DAFM to examine the potential for SRF in Ireland. In addition to reviewing candidate species the project evaluated likely establishment practice and silviculture specifically suited to SRF. The project also set up field trials to assess the impact of stocking density on growth and yield. Further work also assessed the quality and calorific value of biomass produced by key species and the sustainability of suitable management / production systems.

KEY SPECIES AND CHARACTERISTICS

The main species of particular interest for SRF in Ireland which ShortFor examined were Sitka spruce, Italian alder and eucalyptus (Eucalyptus nitens). Leslie et al. (2012) recommended that the eucalyptus species most suitable for Irish conditions are E. nitens, E. globulus, E. delagatensis E. muelleri and E. urnigera. The project also suggested potential from Notofagus spp., hybrid aspen and poplar cultivars, coastal redwood, sweet chestnut, paulonia, birch and sycamore. ShortFor established three field trials to examine species growth across varying site types and at a range of planting densities (Table 1). Baseline measurements were taken of height, diameter and survival after year 1. In the future these trials should provide extremely useful data to assess productivity and how this is affected by planting density.

Field trial site	Species
Johnstown Castle (2014)	Sitka spruce (Washington provenance) Eucalyptus nitens Italian alder
Brownswood, Portlaw, Co. Waterford (2015)	Sitka spruce (Oregon provenance) Grand fir Eucalyptus nitens Italian alder
Mountain West, Oranmore, Co. Galway (2016)	Sitka spruce (Oregon provenance) Coastal redwood Eucalyptus nitens Eucalyptus rodwayi Italian alder

Table 1: ShortFor established three species growth trials. (Planting date in brackets)

An online database was developed detailing the wood fuel characteristics of many Irish-grown tree species. The database includes values for moisture content, basic density, ash, ash melting behavior, calorific value, carbon, hydrogen, nitrogen, chlorine, sulphur, oxygen, arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. The species currently represented in this database are alder, ash, birch, lodgepole pine, Norway spruce, Sitka spruce, hybrid poplars, Eucalyptus delegatensis and Eucalyptus nitens. For each species, data are presented separately for the stem, wood, top, bark, branch, and foliage. The database can be accessed at www.forestenergy.ie.

Eucalyptus stands had higher basic density than poplar (De Miguel Muñoz, 2020), an average of 412 kg m^{-3} compared to 297 kg m^{-3}, and were also higher than conventionally grown Sitka spruce (364 kg m^{-3}). Fibre and energy markets prefer higher density wood, due to the impact of basic density on the volume weight relationship and on energy content. Therefore, denser species like eucalyptus are preferred by fibre and energy markets.

PRODUCTION POTENTIAL

Site quality and management practice largely determine mean productivity, but the product size and rotation length needed to attain the site carrying capacity is largely governed by planting density. Biomass productivity from eucalyptus plantations appear likely to produce up to 180 t oven-dry biomass (odb) in rotations of up to 22 years, having been established at a density of 2,500 stems ha^{-1}. Foreman (2019) modelled the productivity of a series of species at varying establishment densities and estimated that rotation length was substantially shorter for E. nitens than for Italian alder or Sitka spruce and the estimated stand volume and biomass yield were greater, regardless of planting density. The model predicted that a stocking of c. 3,900 stems ha^{-1} (c. 1.5 × 1.5 m) would maximise biomass yield of E. nitens, producing an estimated above-ground biomass of 150 t ha^{-1} (670 m^3 ha^{-1}) at 15 years before production would plateau and start to decline. Recently used planting densities for E. nitens have been c. 1,800 - 2,000 stems ha-^{1}, but this was based on scant data (Thompson et al., 2012), and rotations of just over 20 years are required. The results of this study indicate that a higher density would be preferable to maximise production over a shorter rotation period. The Foreman study found that Sitka spruce was most likely not suited to rotations as short as 15 to 20 years as it would involve harvesting before it achieved its greatest biomass production potential. The results from the study clearly show that this species would not be suitable for biomass production at rotations of less than 30 - 35 years (happily confirming conventional forestry practice!). The modelling results indicated that a higher stocking level than is currently used in practice is likely to increase biomass yield in E. nitens. If a 15-year rotation length was selected, the growth model indicated that planting density should be increased (to c. 3,900 stems ha^{-1} (1.6×1.6 m) from the currently recommended 2,500 stems ha^{-1} (2×2 m).

Figure 2: This image illustrates the potential increase in biomass available from a highly productive 18-year-old E. nitens stand compared with a Sitka stand a year older. The E. nitens was ~23 m tall, whereas the spruce was ~12 m tall (Thompson, 2012).

ENVIRONMENTAL IMPACT

The ShortFor LCA study examined the GHG emissions mitigation potential of using SRF biomass and conventional forest harvest residues to displace the use of milled-peat at the Edenderry Power Ltd. Plant in Co Laois. When assessing the Irish options for meeting its overall electrical energy demands and maintaining a nominal level of energy security, while simultaneously partially fulfilling its renewable energy and climate change mitigation related commitments, only one of the tested scenarios addressed all four issues. That scenario was the complete displacement of milled-peat as fuel at the plant by SRF produce or forestry biomass residue. Currently Edenderry is the only power generation plant equipped for co-firing with biomass, and with the potential for exclusive biomass combustion.

It was found that SRF afforestation could increase organic carbon release from soil. As E. rodwayi had the lowest organic carbon release concentration, it could be considered for more sensitive catchments (such as peatlands) where high organic carbon release is a concern. SRF tree species (E. nitens, Italian alder, E. rodwayi) had higher P-uptake efficiencies than spruce and lodgepole pine. Replacement of the latter by SRF tree species could significantly reduce P-release from soil to water bodies. This makes SRF tree species suitable for P-sensitive catchments. It also indicated that SRF might also be used strategically for remediating biowaste and for watershed management, of course while also implementing suitable buffer zones in riparian circumstances. The relative GHG-performance of SRF systems depends on the nature of the harvesting (degree of soil damage) and the components harvested. It looks likely that stump or root harvesting would significantly affect the sustainability of continuous short rotations, as would the harvest of foliar components. As a result it is recommended to harvest debarked stems for biomass use in the UK to ensure sustainable productivity.

KEY OPPORTUNITY? AS A *TARGETED COMPLIMENT* TO CONVENTIONAL FORESTRY

The reasons SRF is not more widespread to date have been primarily economic! Land prices in productive farming areas are high. The cost difference between fossil fuels and renewable resources such as woody biomass needs to be substantial before it makes economic sense to manage SRF. In addition, there has been considerable skepticism among the public and landowners in relation to other biomass generation schemes (e.g. the miscanthus debacle). However, political and popular opinion may well swing in favour of SRF soon because of the continued requirement for renewable carbon-neutral fuels and fiber sources. In addition, there is also a growing realization (across Europe in particular) of the national value of greater energy and resource independence. However, in a survey of market stakeholders in Ireland and Oregon, De Miguel Muñoz et al. (2016) found that other more profitable markets can develop for using SRF and will compete with fibre and energy end-users. Indeed, financial analysis carried out by the same group found that the best economic outcome for growers resulted from the production of a mix of products including pallet wood with the fiber and energy products.

De Miguel Muñoz (2020) also noted a classic chicken-and-egg circumstance; that SRF markets can only be developed if a minimum supply is guaranteed, but establishment of SRF can only be promoted if markets are assured! So, the study concluded that long-term agreements between landowners and end-users would be needed so both sides could reduce investment risks. The study also concluded that formation of associations of small growers would also satisfy the preference of industry for not engaging with individual private forest owners.

One of the key recommendations from the ShortFor study was that SRF holds considerable potential for productive and economic returns for growers and the energy industry, however the requirements for suitable site types and proximal locations to end-use markets, makes this specialised system suitable for targeted deployment to compliment market infrastructure and existing conventional forest resources. Further research into yield models for eucalyptus' and other suitable species' growth in Ireland would facilitate quantification of biomass over time, and provide a basic tool for forest planning and resource optimization.

Authors:
Brian Tobin, Susie Foreman, Conor O'Reilly – UCD Forestry, University College Dublin
Niall Farrelly, Ian Short – Teagasc
Ken Byrne, Mike Clancy – University of Limerick
Liwen Xiao, Mark O'Connor – Trinity College Dublin
Tom Kent, Ana de Miguel Muñoz, Enda Coates, Brian Cronin - South East Technological University, Waterford

Figure 3: An example of an upper-stem log from a 21-year old Eucalyptus delegatensis stand grown at Kilbora, Co. Wexford.