A comparison of market opportunities for short rotation forestry in Ireland and Oregon

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Abstract

Short Rotation Forestry (SRF) is the practice of cultivating fast-growing tree species mainly for the production of biomass. In Ireland, SRF rotation lengths are less than 20 years. SRF forest cover is expected to increase in response to the increasing demand for fibre products and renewable energy targets set by the European Union. Although Irish policy supports the establishment of SRF, prior research identified Irish forest industry concerns over the market opportunities for SRF, which may limit its establishment. A SRF market was successfully established in Oregon, U.S., mainly based on hybrid poplar (*Populus* spp.). A survey was carried out there and its results were supplemented by US-based literature. The objective was to benchmark conditions that facilitated market development in Oregon with current conditions in Ireland, to identify and describe gaps and opportunities that hat could be applicable to growers and potential users of SRF in Ireland.

The key success factors in growing and marketing SRF in Oregon were large-scale plantations, local supply chains, consistency of supply, FSC certification and the targeting of high-value products. Small-scale plantations and low-value product systems were unsuccessful in Oregon. However, liquid biofuels and payment for ecosystem services are new opportunities currently in development. These options could also be applied in Ireland to motivate SRF development and improve the sustainability of these plantations.

Keywords: *Hybrid poplar,* Populus*, pulp, wood energy, wood market survey.*

Introduction

Historical development of hybrid poplar in Oregon

In 1893 the first poplar plantation was established in the Pacific Northwest (PNW) (Bourque et al. 2014). The potential of combining western black cottonwood (*Populus trichocarpa* Torrey and A. Gray), a native poplar in the PNW, and eastern cottonwood (*Populus deltoides* W. Bartram ex Marshall) was realised by tree breeders in this region in the early 1970s (Carlson and Berger 1998). Located in the PNW, where many Irish forest species originated, Oregon State invested significantly in research and commercialisation, so that new markets were developed in hybrid poplar production

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and processing. Hybrid poplar was first used as a fuel (Hansen et al. 1983) and then planted to meet the forecasted shortage in pulp for the paper industry (Figure 1). Initial stocking of 1,500 trees ha^{-1} could produce 62 to 100 dry tonnes (dt) ha^{-1} of clean chips and additionally from 22 to 33 dt ha^{-1} of residue biomass on a 7- to 10-year rotation (Stanton et al. 2002).

Farmers established hybrid poplar plantations, motivated by the potential profits indicated by research and supported by the paper mill markets. Although there were no specific grants for afforestation with hybrid poplar, some landowners could avail of cost sharing funds from the Agricultural Stabilization and Conservation Service if rotations were over 10 years (Heilman et al. 1990) in order to enhance the environmental benefits resulting from a longer rotation. Small landowners' plantations ranged from a few hectares up to 100 ha (Figure 2).

Also, in the eighties and nineties, five pulp and paper mills established significant poplar plantations (a minimum of 3,000 ha each) with the aim of supplying material for their own production (Bourque et al. 2014). In 2002 it was estimated that there was over 20,000 ha of hybrid poplar in the PNW (Stanton et al. 2002). However, markets did not develop as the forecasts had predicted. The decline of the paper industry and low pulp prices forced the closure of plants and the sale of plantations resulting in a reorganisation of the ownership structure.

Boardman plantation

An example of the industrial development of hybrid poplar SRF in Oregon is the poplar plantation in the Boardman region of eastern Oregon. Although this is a very dry area, the land has water rights from the Columbia River so the poplar plantation was irrigated. Established in 1992 for the pulp and paper mill, this 7,000 ha plantation and on-site chip mill were acquired in 2007 by GreenWood Resources, a timber investment and asset management company, with the aim of finding new markets

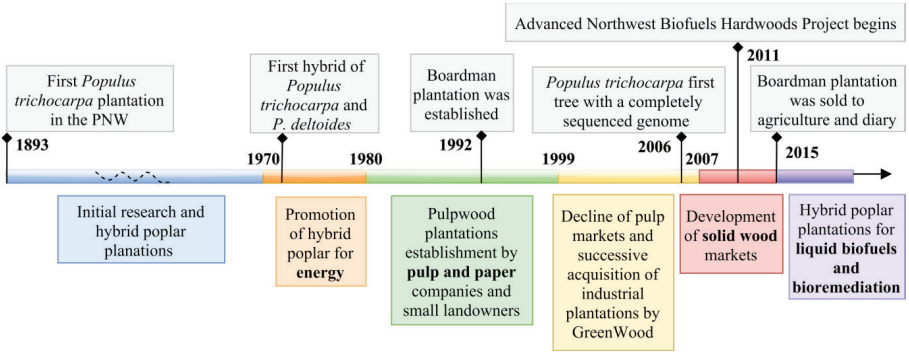

Figure 1: *Timeline describing the use of hybrid poplar in SRF systems in the Pacific Northwest.*

Figure 2: *Whole-tree harvesting of a 12-year-old 60-ha hybrid poplar plantation belonging to a small landowner in the Willamette Valley, Oregon in 2004. (Photography credit Don Wirth.)*

for higher-value products from hybrid poplar (Rinaldi 2015). GreenWood invested in research and innovation on silvicultural practices and clonal material to improve productivity and disease resistance (Stanton 2005, Stanton 2011) and to develop expertise in hybrid poplar management.

In 2008 a sawmill was built in the middle of the plantation (Figure 3), while in 2013 a veneer mill to manufacture plywood was established next to the sawmill. Products such as wine boxes, ceilings, pencils, and interior frames for furniture were made from boards produced from the sawlogs. The plywood was used mainly to produce cabinets. The residues were used for pulp for the paper industry and for energy. The poplar plantation increased to over 10,000 ha through subsequent acquisitions (Rinaldi 2015). However, in 2015 the plantation was sold and is now in the process of being converted to agriculture. GreenWood still owns another 2,000 ha of poplar in west Oregon that is mainly used for pulp, paper and veneer production.

New opportunities for SRF in Oregon

Currently the $40 million Advanced Hardwoods Biofuels (AHB) project, funded by the U.S. Department of Agriculture, is investigating how to develop a renewable transportation

Figure 3: *Boardman poplar plantation and sawmill. Oregon, August 2016.*

fuels industry by growing and converting hybrid poplars into liquid biofuels. Poplar for biofuel use is grown in a coppice system on a three-year rotation (Figure 4).

Poplar is a suitable feedstock for energy generation due to: 1) its ability to coppice and accumulate biomass quickly, 2) its suitability to grow strongly on marginal lands and 3) its wood composition which is adequate for the conversion process (Budsberg et al. 2016). However, low fossil fuel prices and lack of economic incentives for renewables make the viability of biofuels a challenge. Furthermore, poplar plantations will need to be of sufficient scale to fuel biorefineries all year round and be located near the refineries to reduce transport costs. The production of plant-derived biochemicals (such as paints, plastics, packaging, and cosmetics) is being investigated to improve financial viability (Crawford et al. 2016).

Another option for poplar being explored in Oregon is the payment to forest owners for the provision of ecosystem services such as carbon storage or remediation of pollution (Figure 5). There is increasing interest in such payments and approximately 5,000 ha of poplar plantations are grown primarily for environmental services in the PNW, although at this time only 2% of municipalities have applied this system (Gustafson 2016). In addition, hybrid poplar wood has been tested for engineered wood product manufacture such as Cross Laminated Timber (CLT). While initial tests indicated that it met strength requirements, it did not pass stiffness specifications. Mixing poplar wood with higher density species had the potential to improve stiffness results (Kramer et al. 2013).

An exploration of the market opportunities for SRF in Ireland was carried out

Figure 4: *A three-year-old second rotation hybrid poplar coppice plantation, ready for harvesting, chipping and converting in liquid biofuel for energy generation in Jefferson, Oregon. October 2016.*

by de Miguel et al. (2016). This study aims to benchmark the conditions in Ireland identified by that publication with those that facilitated market development in Oregon. Benchmarking design and analysis involves identification of good practice cases, rigorous study of one's own practices (e.g. using site visits and interviews), and development of recommendations for potential implementation (Garvin 1993, Hothorn et al. 2005). This methodology has been applied in various forestry sectors, such as for the development of clone propagation methods (Pilbeam 2004), forest certification (KCBS 2006), forest biodiversity (European Commission 2011) and the wood products industry (Mitchell 2012).

The main objectives of this study were 1) to identify the conditions in Oregon that facilitated the successful implementation of SRF and 2) to identify gaps between the circumstances in Ireland and Oregon that may deter development of SRF in Ireland, and to suggest ways to address such issues. Previous work revealed the Irish wood energy sector and pallet industry may be favourable towards using SRF, but other

Figure 5: *Hybrid poplar at the Biocycle Tree Farm in Eugene, Oregon. This plantation recycled wastewater treatment by-product from two cities, Eugene and Springfield. Trees were harvested every 10 years to generate revenue to balance against operating expenses. In the background an eight-year-old stand can be seen. In the foreground a stand replanted a few months before the photograph was taken in October 2016. (Photo credit Rick Zenn.)*

market sectors were negative about SRF, citing doubts about wood properties and lack of sufficient supply of raw material (de Miguel et al. 2016). That survey identified the need to provide the industry with the following information: wood properties of SRF-grown species; suitability as a wood fuel; the current afforestation grant supports for SRF. This survey of the Oregon SRF sector aimed to reveal perceptions on the suitability of SRF material for different products in Oregon and to discover the drivers that initially gave industry confidence to use SRF systems. The survey aimed to investigate the availability and importance of information on the characteristics of the raw material. The scale of annual raw material production required in Oregon, and balancing of supply and demand, will be described, as this was considered an important prerequisite by the Irish processing sector in potentially using SRF material.

Materials and methods

Benchmarking analysis was the process used to understand and learn from good practice case studies of SRF hybrid poplar production in Oregon. A survey of the hybrid poplar industry chain in Oregon was completed by semi-structured interviews

of industry stakeholders, following the same methodology described in de Miguel et al. (2016). Fourteen interviews were carried out between August and October 2016 in Oregon. The sample was chosen mainly by the snowball technique, whereby new survey participants were nominated by some interviewees. As the target was to compare the survey results to those previously described for current Irish conditions, purposive sampling was followed, so markets not currently in Ireland, such as pulp and paper mills, were ignored. Seven users of SRF-grown material in Oregon, made up of primary and secondary wood processors, were identified and interviewed. To develop a comprehensive understanding of the case study, it was necessary to capture perspectives of people from different points of view, so poplar growers were also interviewed. These other interviewees were two small forest landowners, two university extension officers advising hybrid poplar growers, and three managers of larger scale plantations (Table 1 and Figure 6).

The triangulation method, meaning validation of the survey responses from other sources, was used to verify the data collected in the interviews (Patton 1999, Carter et al. 2014). Three researchers involved in hybrid poplar development in Oregon confirmed the information supplied by the interviewees, filled in gaps and provided additional background information. Also, relevant literature including harvest reports, market survey reports, marketing materials, and sawmill technology information, were reviewed and included in the analysis. Consistency in general patterns was expected. However, when there were contrasting findings from different sources, reasonable explanations were given and in this way they contributed to the overall credibility of the results (Patton 1999). Another difference to the study in Ireland was that survey results focused on qualitative analysis only as the objective was to identify conditions that facilitated SRF development. Questions focused on perceptions of using hybrid poplar in SRF, specifications of raw material, supply-demand balance, and source of the raw material. Interviews were transcribed and the software N-Vivo (QRS International Pty Ltd., Australia) a qualitative data management tool, was used to analyse them.

Results from the Oregon study were compared to results from a similar survey carried out previously in Ireland (de Miguel et al. 2016). This comparison was carried out using the benchmarking potential analysis methodology (Garvin 1993) that involves the identification of good practice cases and the development of recommendations for potential implementation. Oregon good practices and strategies for success were identified and recommendations for gaps and weaknesses recognised in the Irish survey were developed.

Results

The number of interviews was smaller than for the survey in Ireland, but more homogeneous since all interviewees were directly involved in the SRF hybrid poplar sector.

Table 1: *Numbers of survey participants and their categories.*

Target group	Sector	Number of participants	Interview type
SRF users	Primary wood processors (sawmill and chips mills, veneer mill and biomass power plant)	3	Face-to-face
	Secondary wood processors (sawlog users, plywood and briquettes)	4	Face-to-face (2) Phone (1) Email (1)
SRF growers	Managers	3	Face-to-face
	Small landowners	2	Face-to-face
	Extension agents	2	Face-to-face

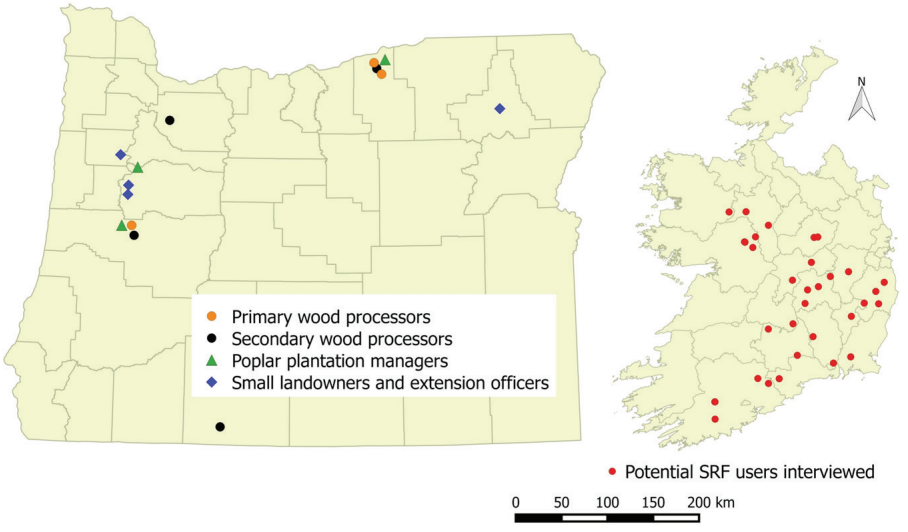

Figure 6: *A scaled comparison between Oregon (left) and Ireland (right) showing the locations of participants in the survey. Oregon has a land area of 25.5 million ha and 48% forest cover whereas the Republic of Ireland covers an area of 7 million ha and forest cover of 11%.*

Perceptions of Short Rotation Forestry in Oregon

Although nowadays hybrid poplar and its wood properties are well-known in Oregon, there was an initial lack of knowledge within the industry prior to using it. Information needs were satisfied by university research and extension, and companies carrying out their own research and testing. Wood processors confirmed that this information was an important factor in enhancing confidence to use SRF hybrid poplar: "We knew it was difficult to machine but I guess it was [required] a lot of testing and trial and error"; "...marketing materials that talked about the properties of the wood, so that you could compare to other species; ultimately you just have to try it. You just have to run it and see how it does."

Specifically, it was important to compare poplar wood property values with those of the most common species used at the time and to define expected poplar grades.

> ...this [wood properties information] was very important early on when we were introducing the species to the customers; they said what are they like? What are the properties? Compared to pine, compared to alder? So this was really useful early on.

In addition to the lack of knowledge on wood properties, hybrid poplar suffered from a bad reputation in the forest industry, which was another barrier to its introduction. Industry had preference for other species or specifically preferred not to use poplar. Initially, the majority of the sawn board production was exported to Asia but subsequently it was accepted in the PNW and markets were developed locally. Hybrid poplar wood became a competitive commercial species in the PNW and there was potential to increase plantation area. One of the marketing strategies was to rebrand poplar wood as Pacific Albus to eliminate negative perceptions about poplar and cottonwood (Figure 7).

> Pacific Albus grows only in that plantation in Boardman....since the plantation closed, we are looking at other sources of poplar in other parts of the world...but it would not be Pacific Albus, it would be some other types of poplar.

Figure 7: *SRF hybrid poplar is promoted as Pacific Albus wood, here showing different board grades.*

Regarding willingness to use SRF, all the companies interviewed reported a willingness to continue using poplar. Users of poplar from the plantation in Boardman were very disappointed that their log supply would cease as they saw many advantages on using hybrid poplar: "there were many, many positives for us; it is very disappointing that it is going away...I was sorry to see it go"; "We have loved Pacific Albus for our market. We will really miss it!" Managers at Greenwood confirmed the strong demand from processors, and expressed disappointment that the plantation was being sold for conversion to agriculture.

However, small forest landowners were not willing to establish hybrid poplar. Although hybrid poplar for liquid biofuels is currently being promoted, they had some concerns to establish new poplar plantations due to previous difficulties in marketing poplar to end-users.

> Now cottonwood [hybrid poplar] has come back in the last few years: the excitement has been for biofuels...they have been asking us and they haven't been getting a lot of enthusiasm from us.

Raw material: quantity, suppliers, distance

The majority of the hybrid poplar raw material sold in Oregon came from the Boardman plantation which grew >10,000 ha of SRF. However, a third of the plantation had already been harvested at the end of 2016 and the land was converted to agriculture. The amount of hybrid poplar from this plantation will be significantly lower in the coming years until the SRF plantations have been completely cleared. In future, harvested roundwood will only be used to produce veneer, as the sawmill has already been closed. Although there is an obvious gap in supply, owners of smaller scale plantations think they will still have difficulties in marketing hybrid poplar timber. The reasons provided seem to be the small volumes individual forest owners can produce and the long distance to supply to markets, particularly for low-value products.

> [The veneer mill] was happy. They took the poplar and made some plywood sheets out of it...later on he [the veneer mill] said: you know, we buy so much volume that this is actually more hassle...then I realised we were pretty small fish in a big pond here in terms of wood products.

Companies confirmed they did not like dealing with small landowners as they needed consistency in supply.

> We need a lot of quantity, that's why we like the Boardman plantation because it was a large plantation with specific quality. We are not interested in buying a few poplar here and there,

> because the quality varies a lot with location; so we try to work with large plantations as they can supply us quite a bit of wood on a regular basis for the long term.

Requirements of raw material

Supply consistency seems to be an essential requirement for SRF users. Boardman material users highlighted the advantages of a secure supply and also the uniformity of the material as it came from the same plantation: "In general for people who want to use poplar they like large plantations because they want the consistency of the supply but also the quality".

Price was another characteristic that made hybrid poplar attractive: "...very economical price-wise...stains well to look like other premium hardwoods, looks like solid maple, but a lot less money."

The particular appearance of hybrid poplar wood, its light colour and weight were also considered advantages for sawn timber products: "The nice thing about hybrid poplar is a very light colour, so if you start with a light colour you can make every colour, if you have alder, walnut, you can't make it lighter"; "One of the nice things of Pacific Albus is the light weight...most of the time what happens is it gets used internally in a product, with the exception of the wine boxes, but our customers like the look."

Among the other advantages of using hybrid poplar from the Boardman plantation was its FSC (Forest Stewardship Council) certification status, a particularly appreciated aspect in the marketplace.

> ...even though it was a lower quality wood, the fact that it was certified helped it to be accepted by some of our customers. We are looking now at some certified woods to replace Pacific Albus because there is a need for it.

Other plantations also confirmed certification was required for them to market SRF poplar for sawn timber or veneer: "If we can grow the stuff and meet their expectations, and we are FSC certified, without that there really doesn't seem to be anything doing..."

On the other hand, there were some challenges regarding wood properties of hybrid poplar, partly because of the change of market, from pulp production to the sawn-board market. For instance, clones with higher yield for pulp production presented problems with straightness for sawn timber or with distortion during the drying process. Industry solved these problems by adapting their production technology and processes to these particular wood characteristics.

> We said ok you got a curvy tree, we solved by using curved log scanning technology...if you trying to follow the log curvature

> you are going to reduce your slope and grain, you are going to have a better quality piece of lumber, better recovery...the long term was to try to grow the tree straight

Secondary producers also found some challenges at first working with poplar wood including: the roughness of the finished products; learning how to stain it; and the type of fasteners to use; but again they adapted to poplar wood properties.

> The biggest problem was the poplar makes a fuzzy, a very rough surface, so it requires different tooling, more steps, sometimes sanding maybe. We had to assume that we were able to make it work, but definitely that was challenging. A bit more difficult to work than other woods.

Hybrid poplar wood fuel was used in biomass power plants and sawmill residues were also used to produce briquettes. Some challenges identified for using hybrid poplar as a wood fuel were moisture content, contamination due to leaf content and inability to meet the prices achieved in other poplar wood markets such as the pulp and paper.

> ...it is worth about twice as much in the form of chips [for pulp and paper] as what we can pay bringing in to burn in our facility. Poplar has a relatively high moisture content and that is a problem when it comes to renewable cogeneration power...if we could get the whole tree yes, but my concern would be that it would be a very expensive fuel for us at that time...if they couldn't sell it to the pulp mills then yeah.

Balance of supply and demand

Regarding raw material for pulp and paper, contrary to the forecasts, production in this sector decreased as demand for paper declined so there was no longer a raw material shortage and pulp prices reduced. In addition, not as many landowners as expected planted hybrid poplar. Those that did had difficulties in selling the timber and in some cases they have not harvested or have harvested at a loss just to convert the land to agriculture.

> What got me into it was we live in a world of poplar here. I just thought there was going to be a shortage of pulp and there is fewer mills than there was...I ended up with those of them that didn't sell so I had 40 acres that I burned.
>
> There is a couple of growers in the region who had some history of it and at some point they said I am getting out and there is a couple that weren't as involved and left it, like the guy who called me the other day: there is a 30 years old stand, giant, I don't know what he is going do with it.

Before the Boardman plantation was sold in 2015, demand for sawn timber and veneer was increasing and expansion of hybrid poplar growing was required as some businesses were planning to expand: "I have felt that demand has grown beyond supply, as it relates to the Superior Grade [clearest grade]"; "I would say it was pretty well balanced, but there were times, some times when we wanted some of the higher grade material and we couldn't get it."

After the large Boardman plantation was sold there was a gap in supply and users have concerns about how to replace the poplar wood that has been the mainstay of some of their products and that they were basing expansion around. They had to look for other species to replace poplar as there was not enough poplar in Oregon to replace the amount that was produced by Boardman: "We are looking into different species: finding poplar is very difficult"; "Yes, a big concern. We need to find a replacement for Pacific Albus now. We are not sure what we will do."

Potential markets

Liquid biofuels, payment for ecosystem services such as carbon and bio-remediation, and engineered products such as CLT are options currently being explored for poplar plantations. However, managers and landowners think these potential markets will still take some years to develop, so they need to find some replacement markets until then: "Being optimistic but also being realistic, probably 20 years down the road the stuff becomes biofuel feedstock. We need to create some markets in between and build up the amount of poplar that is being grown."

The variability in the price of crude oil plays an important role in the viability of biofuel refinement from biomass.

> Back in 2011 oil was up over $100 a barrel and at that point making fuels from feedstock was pretty economically viable, but since then the price of oil has dropped down to about $40 a barrel, which makes it very difficult to compete with making fuels and chemicals from biomass sources.

Benchmarking potential analysis

Results described above were compared to the results from the previous survey in Ireland. The parameters evaluated were land use classification of SRF, availability of grants, availability of information e.g. wood properties, initial level of knowledge about SRF, reputation, willingness to use, past experiences, quantity of raw material, industry preferred source of raw material, distance of supply, requirements of raw material and potential markets identified (Table 2). The same requirements that had been recognised in the survey in Ireland (e.g. supply consistency) were then evaluated in relation to poplar in Oregon.

Table 2: *Analysis of benchmarking potential for use of SRF in Ireland, in comparison to Oregon where SRF plantations and markets were established and well developed.*

Parameters	Ireland	Oregon	Key factors for development of SRF in Oregon
SRF land use	Forestry	Agriculture (maximum of 12 years rotation)	Although no funding available, reduced risk as it was possible to revert to agriculture
SRF grants	Forestry for fibre afforestation grants	No afforestation grants specifically for SRF	
Information availability	70% identified gaps and needs	No information initially, now available	University and/or industry research and knowledge transfer through extension foresters
Initial knowledge	76% not familiar with SRF	Not familiar initially, now familiar	Dissemination by sawmill, university and extension
Reputation	Poor	Initially poor, now good	Marketing: renamed as Pacific Albus Proven processing experience and market
Willingness to use	30% favourable	100% of industry favourable, not initially	Research, own testing, marketing, repeat customers
Past negative experiences	*Miscanthus* and SRC willow	Hybrid poplar for pulp and paper	Marketing, testing and extension dissemination
Quantity of raw material	Targeted 3,300 ha from 2014 to 2020 (DAFM, 2014)	Industrial plantations (over 12,000 ha in 2015) plus small plantations	Large scale, 10,000 ha plantation
Industry preferred source of raw material	Not from small landowners	Not from small landowners	Large scale industrial plantation
Distance of supply	Anywhere in Ireland, but no more than 50 km for wood fuel	Mills on site, secondary wood processors first in Asia, then in PNW	Locally sourced log supply
Requirements of raw material identified in the Irish survey and evaluated by wood processors in Oregon	Supply consistency	✓ Advantage	Large plantation: volume and uniform quality
	Cheap price	✓Advantage	Low cost and fast growing
	Appearance	✓Advantage: light weight and colour	Find niche markets
	Certification	✓Advantage	Allowed entry to new markets or survival in traditional markets
	Straightness	× Challenge	Investment in suitable cutting technology and straighter clones
	Low moisture content	× Challenge	Investment in moisture testing and drying technology
Potential markets	Solid biofuels and pallets	1980-1999: pulp and paper 2000-2015: solid wood products Future: Liquid biofuels and ecosystem services	Flexibility, adaptability and research (different clones better for specific products)

Discussion

Differences between Oregon and Ireland in policy issues such as land use classification and the process of change of use category were identified. While 12-year rotation SRF is considered agricultural land in Oregon, it is considered forestry in Ireland and should remain in forestry as specified in the Forestry Act (2014). Most of the small landowners who invested in SRF in Oregon went back to agriculture due to their inability to market the SRF produce. There were no specific grants for SRF in Oregon, unlike SRF afforestation incentives in Ireland. However, in Oregon landowners had the flexibility to try SRF and return land to agriculture after one rotation. The permanency of the requirement of staying in forestry may be one factor that will limit the establishment of SRF in Ireland.

In line with the findings of the Irish survey (de Miguel et al. 2016), growers and end-users in Oregon initially required information on SRF, particularly on wood and fuel properties. This appears to be an important gap to fill to start market development. Furthermore, product testing by researchers and industry was also needed in Oregon.

Negative perceptions by industry towards hybrid poplar wood were a barrier to the introduction of SRF for sawn products in Oregon and biases towards using SRF were also identified in Ireland. In Oregon this bias was overcome by the marketing strategy of branding the species with the name Pacific Albus, together with dissemination of wood property information and prepared samples. In Ireland, wood property information and product test samples, at least, are needed in order to counter industry preconceptions.

Skepticism of SRF viability was expressed by small-scale poplar growers. The promotion of hybrid poplar to fill the forecasted shortage in the pulp market, which did not happen, dampened Oregon growers' interest in the potential new market for poplar for liquid biofuels. Oil price fluctuations also contributed to increase this reluctance. A similar situation was found in Ireland, where doubts were raised about the viability of SRF due to unsuccessful market development for other energy crops, e.g. elephant grass (*Miscanthus* spp.), previously extensively promoted. A proven and consolidated market could be needed to get these growers investing in SRF.

Development of SRF in Oregon was based on a large scale industrial plantation of 10,000 ha. This was a successful model that only ended due to the plantation land being sold for agricultural development (Stanton 2016). Boswell et al. (2008) estimated that approximately 7,000 ha of hybrid poplar would be needed to develop a sustainable model, considering this the minimum volume to get cost effective production as well as to attract the added value processing infrastructure. However, 3,300 ha is targeted to be afforested with SRF in the period 2014-2020 under the Irish forestry programme (DAFM 2014). Similarities in the volume of raw material supply required by the Oregonian and Irish wood processing industries and reluctance to deal

with many small suppliers (de Miguel et al. 2016) indicate that large-scale plantations will be needed to develop markets in Ireland. Production scale may be achieved in two ways: 1) the industrial approach followed in Oregon by GreenWood; or 2) by forming effective producer groups of small forest owners with clustered plantations. However, this latter approach was not very successful in Oregon (Stanton et al. 2002), as smaller forest owners could neither guarantee the consistency of supply or quality required by users. Distance from plantation to market was also a crucial issue, particularly when low-value products were transported. Both in-situ mills and high-value products were needed for a successful supply chain in Oregon. As low-value products are the main goal for SRF in Ireland, an in-situ end-use or locally available supply would seem to be required.

Similarities were found between Oregonian and Irish companies' preferences for raw material requirements. In addition to security of supply, raw material price and appearance were identified as important to end-users in both surveys. Certification was also a requirement highlighted by the Oregonian sawn-timber industry and is increasingly required in Ireland. The requirement for straight logs for certain products was identified in Ireland. Research, testing and technology adaptability helped to solve these difficulties in Oregon and a similar approach could be adopted in Ireland.

Mixed views regarding the supply-demand balance were found in both cases. While sawmills found difficulties in sourcing their raw material in Oregon and Ireland, woodfuel producers in Ireland and small growers in Oregon found there was more raw material available than demand for it.

Policy requirements in response to environmental issues, e.g. the use of renewable energy, remediation of pollution and construction with renewable materials, were the drivers for development of new markets for hybrid poplar in Oregon and may be options to explore in Ireland. Meeting renewable energy targets provides a suitable reason for the State to heavily incentivise investors or growers to meet these targets. That would provide the impetus to develop a market, from which point ordinary market forces would ensure its success or failure. The wood energy sector was the most favourable to use SRF in Ireland, so developing biorefining to produce liquid biofuels could be an option to explore if sufficient scale of feedstock production was feasible and fossil fuel prices increased.

Conclusion

Oregon developed a model of growing and marketing SRF hybrid poplar based on large-scale industrial plantations, in-situ processing mills, certification and high value product market development. However, small plantations and lower value products were not successful. Furthermore, there is now a shortage of hybrid poplar wood supply in Oregon that will increase to about 400,000 m^3 yr^{-1} when the Boardman

plantation is completely converted to agriculture. However, such a shortfall in supply would not guarantee that an individual grower could secure a financially viable place in this market due to requirements for production scale and log quality that the processing sector demanded. Learning from the Oregon experience, Ireland must consider the importance of scale and management of quality, so the development of co-operative producer groups would be essential. Moreover, industry should provide clear guidance on pricing related to size and quality specifications.

Another lesson from the approach to SRF in Oregon was the need for flexibility to adapt to changing circumstances. Although the wood energy sector was identified as a potential market for SRF in Ireland and a future shortage of woodfuel is expected, market demands can change by the time plantations reach rotation age, as happened in the pulp sector in Oregon. Flexibility of management is an advantage of the SRF model proposed in Ireland, based on single stem trees and 10- to 20-year rotations, and with the possibility of conversion to conventional forestry systems. However, if other markets need to be targeted in the future, then different species, stocking and silvicultural practices may be required.

Although flexibility can help market development, there is a risk of a commercial supply chain ending even when successful markets have been developed. For instance, land competition from other higher value uses can hinder the development of SRF, e.g. another agricultural crop in Oregon or another Grant Premium Category of the forestry programme in Ireland. Research and dissemination actions together with marketing strategies were essential to the development of SRF in Oregon for both growers and markets; the same approach will most likely be needed in Ireland.

Although development of high value products was essential in Oregon, wood energy was the sector most favourable towards using SRF in Ireland. The Oregon experience highlights a series of possible challenges for economically sustainable energy feedstock supply:

- minimum production scale;
- locally available consistent supply of SRF for energy;
- requirement for as short a supply time (rotation length) as possible;
- consideration of coppice techniques to reduce establishment costs;
- need for higher value products to increase financial revenue for the grower.

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