Exploring the Benefits of SRC Willow Planting for Water Quality Protection and WasteWater Management - Workshop

5th March 2020 - Stakeholders Conference and workshop

Report: Chris Johnston (Agri-Food & Biosciences Institute)

Contents

1. Introduction.

The concept of willow crops for bioenergy and willow vegetation filters for the treatment of nutrient-rich wastewater has the potential to address two of our most serious environmental problems today — water pollution and climate change via bioenergy production — in a cost-efficient way. Despite a number of benefits of linking willow growth with waste management which include high treatment efficiency, increased biomass yields, improved energy and resource efficiency and cost savings, willow vegetation filters have so far only been implemented to a limited degree and mainly in a research or proof of concept scale. This is due to various kinds of barriers, which may be the result of current institutional, social, structural and technical/geographical conditions[1]. There currently exist several potential challenges which could help to develop this sector which include …

- Water quality challenges - pressures on freshwater be it on rivers, lakes or groundwater are significant with unhealthy trends on water quality over recent decades.
- Competing demands on the public purse - Improvements are currently required for hundreds of small towns & villages wastewater treatment plants / standalone housing estates around the country.
- Current farming model is strained - smaller fewer intensive farms are experiencing financial pressures.
- Climate Action - Climate Action Plan 2019 identifies how Ireland will achieve its 2030 carbon emissions and puts us on a trajectory to achieve Net Zero Carbon Emissions by 2050.
    - Action 60 - Effectively ban the installation of oil (& gas) boilers from 2022 (2025) in all new dwellings through the introduction of new regulatory standards for home heating systems and ensure the supply chain for the installation of renewable heating systems is in place.
    - Public leadership is included. “The leadership role public bodies can play in taking early action is fundamental to achieving our de-carbonisation goals”.

2. Potential Opportunity benefits

Could growing willow crops be part of the answer to mitigate many of these challenges.

- Water quality protection.
- Flood prevention - willow crops can also be used as part of innovative approaches now being adopted as 'natural flood retention measures' or slow the flow in upper catchments which help remove some of the high energy and destructive nature of floods.
- Agricultural diversification.
- Biodiversity benefits.
- Carbon sequestration.
- Renewable energy Biomass displacing fossil fuels.
- High Value compounds[2].

[1] Pal Borjesson, Goran Berndes. The prospects for willow plantations for wastewater treatment in Sweden. Biomass and Bioenergy 30 (2006) 428–438

[2] Jane L.Ward et al. Miyabeacin: A new cyclodimer presents a potential role for willow in cancer therapy. https://www.nature.com/articles/s41598-020-63349-1.pdf (2020)

- Willow crops can be grown easily in our climate and can be used as a bio-energy source however the market for that purpose is currently weak and we need to develop the supply chain.

There would appear to be real opportunities for agriculture and our agri-land base in Ireland (N & S) to be encouraged to diversify, sequester carbon and improve biodiversity? With the correct incentives farming and land use practices could be adapted to address the current pressures on the aquatic environment whilst also producing a value-added biomass crop.

3. Background

It was recognised at the outset of the CatchmentCARE project design stage that it would be important to understand the baseline interest and commitment certain stakeholders had with regards to the principle of SRC willow planting and indeed how or if these fit with any current national strategies. It was decided that this would be best done by holding a stake-holders conference and attempting to get as wide a stakeholder spectrum to attend as possible. During such an event, many of the roles and benefits of SRC willows could be explored. This report summarises the activities and findings from an event run on 5th March 2020.

4. Rationale for deciding to hold a stake-holders conference

The seeds of this event were sewn during a conference and technical workshop in Dublin on 21st June 2019. The event was the promotion and outlining of the recently launched Support Scheme for Renewable Heat in the Republic of Ireland. Given the potential influence of such a policy implementation and potential for the expansion of biomass energy crop uptake, it seemed prudent to start to think about a cross border event which would explore and hopefully develop the argument and support for promoting agricultural diversification to energy crops.

However, there was a very clear message and discussion point at this event, understood by the majority attendees, that recent perceived policy errors and the collapse of the Renewable Heat Incentive (NIRHI) in Northern Ireland, had caused the sector a lot of financial and reputational damage. It was also clear that the NIRHI had not stimulated any shift in land use nor created any biomass crop policy as a result. Benefitting from the multi-functional advantages of biomass crops such as SRC willow therefore was completely missed and with that, the whole opportunity to develop a sector which could bring valued employment along with environmental improvements was also missed! With the advent of the SSRH therefore, this was a perfect time to try to align these benefits with biomass crop diversification and a stakeholder conference seemed an ideal route to try to develop the dialogue and understanding.

Essentially therefore there was a clear need to assess and discuss stakeholder commitment to the principle of SRC willow planting and indeed how this might fit within national strategies (SSRH, RHI, WFD - water quality protection, sustainable waste management and indeed the upcoming climate change commitments and pending regulations). It was agreed that an association with Teagasc's in developing and holding this event would ensure a more far reaching and truly cross border stakeholder inclusion. AFBI & Teagasc have a long history in working together and in researching, developing and promoting the potential of energy crops. An event was therefore planned and organised by Donegal County Council, AFBI

and Teagasc staff members. An Organisational timeline is summarised in Appendix 1.

4.1. Event publication – Event Date Saver

Exploring the Benefits of SRC Willow Planting for Water Quality Protection and Wastewater Management - Workshop.

- CROWNE PLAZA HOTEL, DUNDALK.
- 5th MARCH 2020, 10:30am to 3:30pm.
- CatchmentCARE (Community Actions for Resilient Eco-systems) is an EU-funded project that aims to improve freshwater quality in cross-border river basins across three cross-border catchments.

4.2. Event Publication - Agenda of talks and workshops

Exploring the Benefits of SRC Willow Planting for Water Quality Protection and Waste Water Management

CatchmentCARE
Community Actions for Resilient Ecosystems

CROWNE PLAZA HOTEL, DUNDALK.
Thursday, 5th MARCH 2020, 10:30am to 3:30pm.

Agenda

10.00 - 10.30	**REGISTRATION**
10.30 -10.40	Welcome and Opening Remarks. Michael McGarvey, Director of Services, Donegal County Council
10.40 -11.00	Overview of CatchmentCARE Project & Environmental context Con McLaughlin, Senior Engineer, Donegal County Council
11.00 -11.20	Greenhouse gas emissions from Agriculture Bernard Hyde, Scientific Officer, Regional Inspectorate, Environmental Protection Agency
11.20 -11.40	Agriculture's role in meeting environmental objectives John Heffernan, AES Inspector, Department of Agriculture, Food and the Marine
11.40 -12.00	Willows for Waste Water Management and Environmental Protection Chris Johnston, Head of Agri-Environmental Technologies Section, Agri-Food and Biosciences Institute
12.00 -12.20	Willow research completed in conjunction with Teagasc at Oak Park Isabella Donnelly, Senior Energy & Environmental Engineer, ORS Limited
12.20 -12.40	Bio-energy in Ireland / Supply chains / Energy targets / Policy mechanism drivers / willow's role in decarbonising agriculture in Ireland Barry Caslin, Energy & Rural Development Specialist, Teagasc
13.00 - 14.00	**LUNCH**
14.00 -14.20	Catchment potential/opportunities Eddie Burgess, Agricultural Catchments Programme Manager, Teagasc
14.20 -14.40	Nature Based Wastewater Treatment Systems - Opportunities & Challenges Mark O'Callaghan, Business Lead - Innovation, Standards and Technology, Irish Water
14.40 -15.00	Multifunctional Benefits of Willow Crops Kevin Lindegaard, Director, Crops for Energy Ltd
15.00 -15.30	Questions & Answer Session with the expert panel of speakers Facilitated by Prof. Alistair McCracken This will include interactive Q&A, live audience polls using Slido

4.3. Event Publication - Accompanying description.

It was explained that a key deliverable for the Project is to undertake an assessment of stakeholder commitment to the principal of Short Rotation Coppice (SRC) willow planting for water quality protection and wastewater management; and how this might fit with national strategies and that the workshop will explore this option.

The event therefore targeted those involved in policy, water, utilities, catchment management, energy, climate change, local authorities to explore the potentials of using willows, mainly as landscape interventions and mitigation of runoff pollution but also how that can contribute to the sustainable energy and climate change challenges we are facing. Lunch will be provided.

4.4. Attendees Targeted

Attendees were from a wide range of disciplines which included …

Advisory Agency Agri policy Agricultural inspector Agricultural Sustainability & Support Advisor Aquatic Biologist	Government Inland Fisheries Ireland Environmental Officer Local Authority Policy & Policy development Poultry

Biomass energy consultant Catchment Scientist CEO Agriculture Cooperative Compliance inspection DAERA senior scientific officer Ecologist Education Engineer Engineer seeking outlets for sewage sludges, Environmental manager Environmental Officer Local Authority Environmental policy Environmental Technician Farmer Farmer, willow planter and grower, biomass producer Fisheries Environmental Officer Funding General forestry operator, forestry student	Public sector Regulator Research scientist Scientific Officer Scientist Scientist CARO ASBN Scientist in local authority Source protection Statutory agency Student Student of forestry Sustainability advisor Teagasc, Teagasc - agricultural consultant & Teagasc advisory Wastewater inspector at EPA Water Policy Manager Water quality manager Water quality and Agriculture research Willow Business Owner Willows, biomass

5. The Presentations – Summaries.

5.1. Welcome and Opening Remarks - Michael McGarvey, Director of Services, Donegal County Council

5.2. Overview of CatchmentCARE Project & Environmental context - Con McLaughlin, Senior Engineer, Donegal County Council

CatchmentCARE project with the Project Outputs being …

Establish 3 water quality improvement projects.

- Arney catchment (304km2)
- Blackwater catchment (1,500km2)
- Finn catchment(494km2)
- and install 50 groundwater monitoring stations across the region.

And that the project will be delivered through a combination of . . .

1. policy actions

1. Refining the current nutrient management advice to farms through the implementation of a farm scale surveys on selected farms.
2. Completion of an evaluation of the cost and feasibility of achieving the WFD objectives in the three catchments
3. Delivery of a scoping study on the feasibility of establishing a willow supply chain in the border region

2. Catchment and water body actions

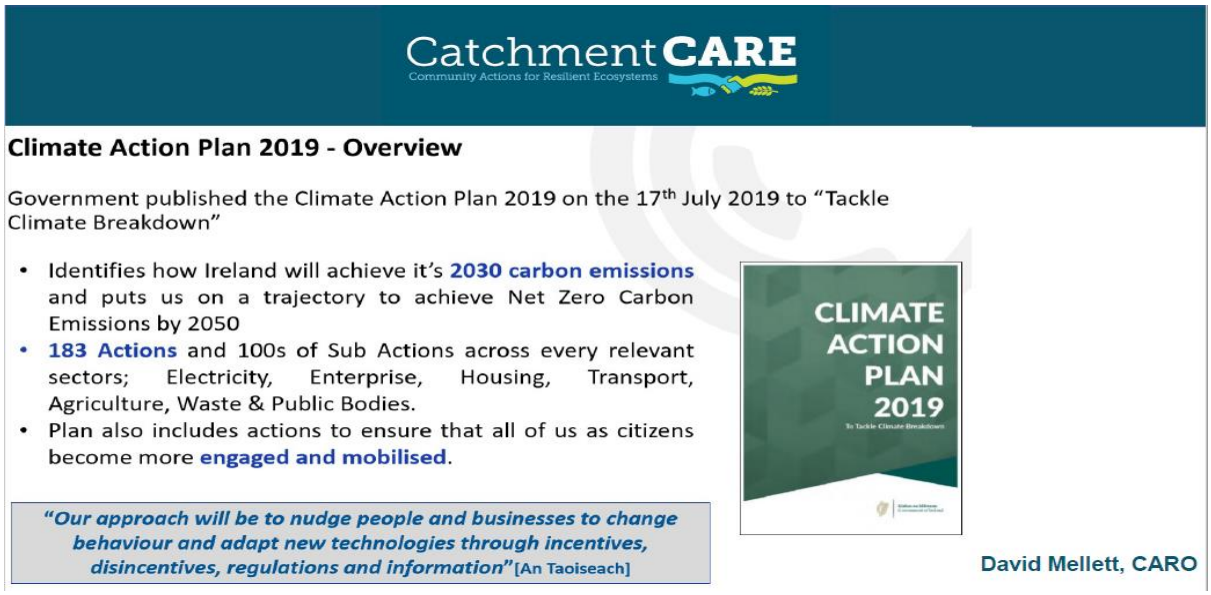
1. LA & IFI & ABC are focussed on in-stream / riparian work, using survey data / local knowledge to maximise the impact of actions in the catchments.
2. Afbi in conjunction with UU – progressing small WWTP upgrades using willow plantations for bioremediation of effluent.
3. UU are exploring the addition of P binding materials to selected lakes to reduce the internal loading of phosphorus.
4. The GW Team are tasked with providing 50 boreholes for groundwater profiling which will integrate with other actions implemented through the project.
5. LA plan to reduce the risk posed by chemical escapes from land use in the Finn catchment.
6. Linked to policy action already mentioned, the Project will provide nutrient management advice to farmers through farmer discussion groups, farm adviser workshops and open days.

3. Enhancing the capacity of local stakeholders to contribute to improvements in water quality Via a Community Incentive Scheme

1. Support communities to take innovative approaches to looking after and caring for their local river systems including associated lakes.
2. (CIS) is designed to:
3. Approx €0.5m set aside within the Project for Community based projects.
4. Projects funded up to the amount of €25,000.
5. First round of the CIS closed in October 2019
6. Groups are now working with our 3 Catchment Officers on procurement.

The trend was very clearly demonstrated that water quality in Ireland has been deteriorating. This is illustrated by Fig 1 which shows that the number of high-status waterbodies is decreasing while the number of poor status water bodies in increasing.

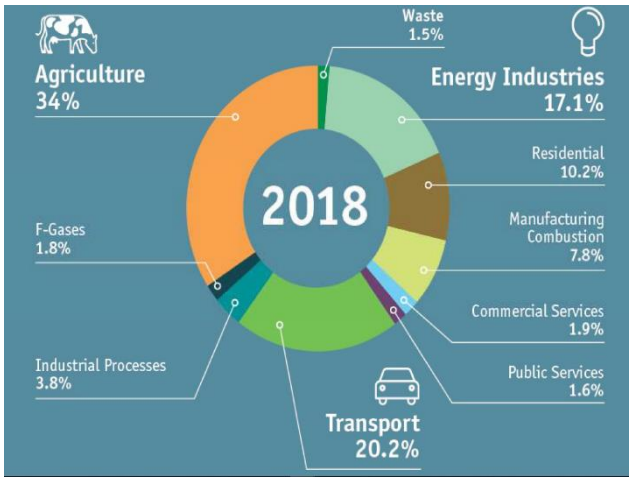
**Delivered as a result of this conference / seminar*



5.3. Greenhouse gas emissions from Agriculture - Bernard Hyde, Scientific Officer, Regional Inspectorate, Environmental Protection Agency

Agriculture is responsible for 34% of Irelands GHG emissions.

a. 58% - Enteric fermentation
b. 10% - Manure Management
c. 30% - Agricultural soils
d. 2% - Liming
e. <1% - Urea Application



Agricultural CH_4 = 93% of national CH_4

a. National Cattle herd = 90%
b. Dairy cows = 33% of cattle total

Agricultural N_2O = 93% of national N_2O

a. N fertilizer = 45% of ag contribution
b. Grazing (urine & dung) = 25%
c. Land-spreading = 14%
d. Management cultivation of organic soils = 13%

Agriculture ~ one third of the key categories

a. Increasing size of national herd
b. Increasing fertiliser use

Agriculture is expected to be 38% of Irelands GHG emissions by 2030.

Actions Required

a. Significant uptake of abatement options needed at farm level required.
b. Climate Action Plan: 16.5-18.5 Mt CO_2 eq reduction in the period 2021-2030
c. Teagasc MACC, AgClimatise, CAP Reform
d. Ability to capture nationally representative data.
e. How can we capture abatement options in national inventories.
f. In breach of NECD – NH3
g. 2010 NECD to 2020, FW2025 in the context of 2020 & 2030 targets
h. 2020 (1%) vs 2030 (5%) reduction on 2005 emission level

5.4. Agriculture's role in meeting environmental objectives - John Heffernan, AES Inspector, Department of Agriculture, Food and the Marine

Ireland's environmental commitments and targets

	Climate	Air	Water	Biodiversity	Renewable Energy
Targets	GHG 10-15% reduction to 2030 Delivery 16.5-18.5MT CO2eq cumulative abatement from 2021 to 2030	The target for Ammonia is 112kt by 2020 and 107kt by 2030	EPA Report 2013-2018 Further Decline in Water Quality. Agriculture responsible for 53%	Agriculture and Land Use significantly impacts on Biodiversity due to agriculture occupying 80% of Ireland's UAA.	Renewable Energy Targets 2020 16% 2030 >16 – 32%

Agricultural diversification to biomass crops such as willow can help address many of these targets by …

Climate	- Fossil fuel substitute to reduce GHGs, carbon sequestration.
Water	- Water quality protection
Biodiversity	- Improved Biodiversity
Renewable Energy	- Contribute to Renewable energy through bioenergy.

However,...

a. Greenhouse gas emissions, Ammonia emissions are increasing while Biodiversity, Water quality and soil fertility are decreasing.
b. Water Quality decreasing while nutrient/€ lost to run-off and water.

Table 1. Main sources of nutrient increases since 2013

Source	Nitrogen (tonnes)	Phosphorus (tonnes
National Herd	5462	164
Human Population	531	162

c. Sub-optimal pH, reducing C stocks,

5.5. Willows for Wastewater Management and Environmental Protection - Chris Johnston, Head of Agri-Environmental Technologies, Agri-Food and Biosciences Institute

The water quality trend in Ireland is illustrated in **Fig. 1**. Which clearly shows that the number of status waterbodies is decreasing while the number of poor status water bodies in increasing.

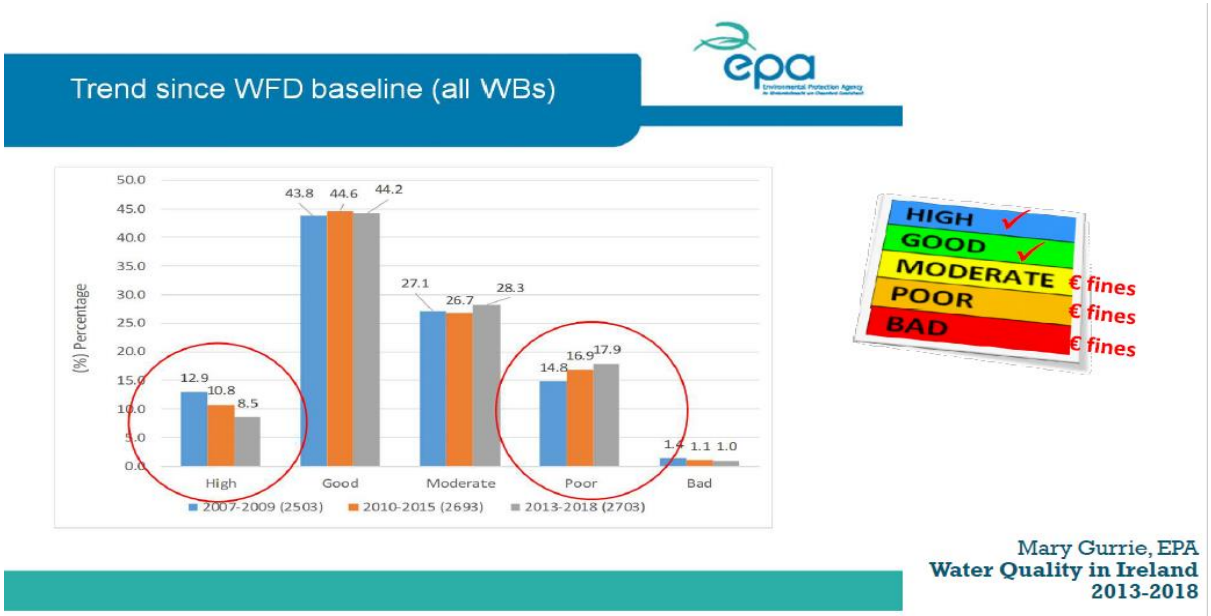


Fig.1. Water Quality trend in RoI

The water Quality of N.Ireland had been improving until about 2010 however since then, it has been deteriorating. The average dissolved Reactive P for 96 rivers is approximately 0.07 mg/l on a backdrop of the WFD limit being 0.03 mg/l. This is mirrored by increasing soil P indices; an increase of 0.31mg/l Olsen P.

In 2016, DAERA launched the Sustainable Agricultural Land Management Strategy (NI) Recommendations[3] which include that Woody riparian strips in overland water flow pathways populated by plants such as willow, which can withstand wet conditions to slow the flow of surface water, collect the sediment and absorb the Phosphorus pre-watercourse, Improve permeability, reduce soil %MC can be coppiced regularly (fuel / value chain) Carbon sequestration, biodiversity, flood alleviation.

In 2007, DAERA funded an AFBI research & development project questioning whether willow plantations could be used to bio/phyto-filter wastewaters from farmyards. The results have shown no indication of negative impacts with a high remediation of water and a substantial uptake in nutrients[4]. The knowledge, experience and interest which this project succeeded in developing gave rise to the successful bid for funding under the Interreg IV programme and brought about the ANSWER project with the main partners of Donegal and Monaghan County Councils along with AFBI[5]. The ANSWER

[3] https://www.daera-ni.gov.uk/publications/sustainable-agricultural-land-management-strategy-report-and-executive-summary
[4] Edward G.A. Forbes, Christopher R. Johnston*, John E. Archer, Alistair R. McCracken, SRC willow as a bioremediation medium for a dairy farm effluent with high pollution potential, Biomass and Bioenergy 105 (2017) 174e189.
[5] https://www.afbini.gov.uk/articles/bioremediation-projects#toc-1

Project succeeded in the planting of over 100 acres of SRC willows for the dual purposes of wastewater management and the simultaneous production of bio-resources for bioenergy. Although at the time bioenergy was, and still is, the prime use of this bio-resource, it is clear that there are other far higher value uses which are currently being developed [2] [6]. Wastewater treatment works (WWTW) with marginally compliant discharges, as a result of infrastructure age and serving population increase, were adapted to irrigate the treated effluent to the willow plantations. One such site in Donegal, Bridgend, has been running since 2014. This WWTW serves a population of approx. 650 people. Historically the treated wastewater was discharged into the river however it is now irrigated onto 3 fields planted with willows. The results from the 2014 summer period revealed a 15% discharge from the plant into the river which was significantly reduced to 7% in 2018 for the growing season when the river is in most often in low flow. The willow crop has been harvested twice since establishment.

Over 50% of the wastewater has been recycled to the willows, on a yearly basis, with this level rising to over 80% when the summer months are viewed specifically (**Fig 2**). It is clear that it is during the summer months when generally rainfall is less, receiving water flow is lower, light and heat availability are higher that the receiving water body is most vulnerable to pollution, eutrophication and ecological deterioration. Maximum benefit can certainly be derived by discharging to the willow crop during this period as conversely, this is when the willow will have a high evapotranspiration rate, protect soil & ground water but also have high nutrient assimilation potential for N & P.

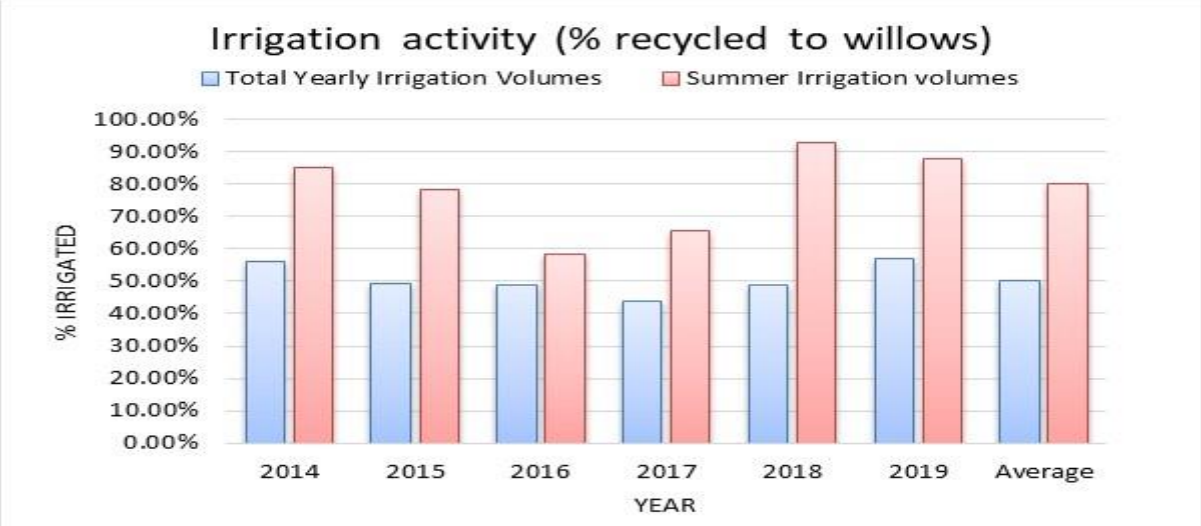


Fig 2. Wastewater Irrigation data from Bridgend WWTW – Co Donegal

A similar logic would also apply for willows placed in the landscape, to interrupt pathways of hydrological connectivity, for water body protection of diffuse run-off. Even though willows will carry out an overland flow impedance function with surface roughness, increased percolation, drainage and water & nutrient uptake through the year, it is during the summer months that livestock is grazing and slurry & dirty water are being spread on land and as such, with increasing rainfall events (frequency & intensity) as a result of climate change, riparian biofiltration blocks can mitigate run-off as a targeted effect.

[6] https://www.nweurope.eu/projects/project-search/biowill/

Fig 3. Biofiltration block protecting waterway from diffuse pollution.

Activities ongoing within EU-WaterPro and EU-CatchmentCARE are demonstrating the extent to which these effects can be realised.

5.6. Willow Agronomy research completed in conjunction with Teagasc at Oak Park - *Isabella Donnelly, Senior Energy & Environmental Engineer, ORS Limited*

Willow - Pioneering crop

a. Willow crops have a C3 pathway which enables plants to photosynthesis at lower temperatures compared to C4 plants
b. Highest Transpiration Rates of any Tree or Agricultural Crop
c. High Bark to Wood Ratio = High Nutrient Removal Rates
d. High Rate of Cutting = Nutrient Removal
e. Ireland – Growing Conditions Suitability to Willow Crops
f. Non-food crop

Good Early Establishment Important

a. Soil Type Important (density, OM, sand, silt, clay, water holding & soil moisture, saturation point.)
b. Luvisol and Brown earth better than Peat, Podzolic or Gley
c. Careful Planting with Good Planting Material
d. Survival
e. Weed Competition is important to reduce.

Conclusion

a. Higher Growth Rate and Yield = Higher Evapotranspiration Rates
b. Establishment and management of the crop in first year important
c. Application of sewage sludge to willow and miscanthus crops does not result in significant build up of soil pathogens provided sufficient lime is incorporated
d. Pathogens are retained and de-activated by soil
e. Enhanced Greenhouse Gas Mitigation

5.7. Bio-energy in Ireland / Supply chains / Energy targets / Policy mechanism drivers / willow's role in decarbonising agriculture in Ireland - *Barry Caslin, Energy & Rural Development Specialist, Teagasc*

LULUCF already offsets almost 1.5m tonnes of emissions per annum.
The conversion of pasture to SRC or SRF has potential to help meet GHG targets.
Realising this mitigation requires:

a. The conversion of a substantial portion of land to biomass
b. Selection of suitable crop types
c. Development of reliable combustion systems
d. Rigorous measurement of emissions and carbon sequestration during cultivation

Role of biomass production in GHG mitigation

a. Displacement of fossil fuels
b. Carbon sequestration
c. C input into the soil – association with the conversion of tillage land to biomass – between
    1. 2.8 – 4.1t CO_2 / ha / y for miscanthus and 1.8 – 2.7t CO_2 / ha / y for willow
    2. If below ground biomass was included, it would add another 0.5 – 1 t CO2 ha

Economics

Establishment Cost	- €7.90/dry tonne - (€2,600 per ha – grant)/22years/9 tonnes per ha)
Harvesting Cost	- €27.80/dry tonne - (€500 per ha)/2 yearly/9 tonnes per ha)
Drying Cost	- €18.00/dry tonne
Haulage Cost (100km)	- €20.00/dry tonne
Lost revenue	- € 27.80/dry tonne (other crops?)
Total cost to produce	- € 81.50 SELF SUPPLY (cost per kWh = €0.016)
Sell with profit	- € 130.00 SELL to END USER (cost per kWh = €0.026)

Crop Value ref. Average oil price of €0.08/kWh
Value per dry tonne (at 5000kWh/t) = €400/tonne (€3,600/ha)
Sell with profit (€30/t) = approx. €400/ha

Farmer supply chain
Farm gate price offered by contractor = €20/fresh tonne (approx. 55% MC)
Two-year harvest yield = 44 wet tonnes = €880/harvest
Dried to 15%MC = 23.3 tonnes = €37.77 per tonne at 15% MC

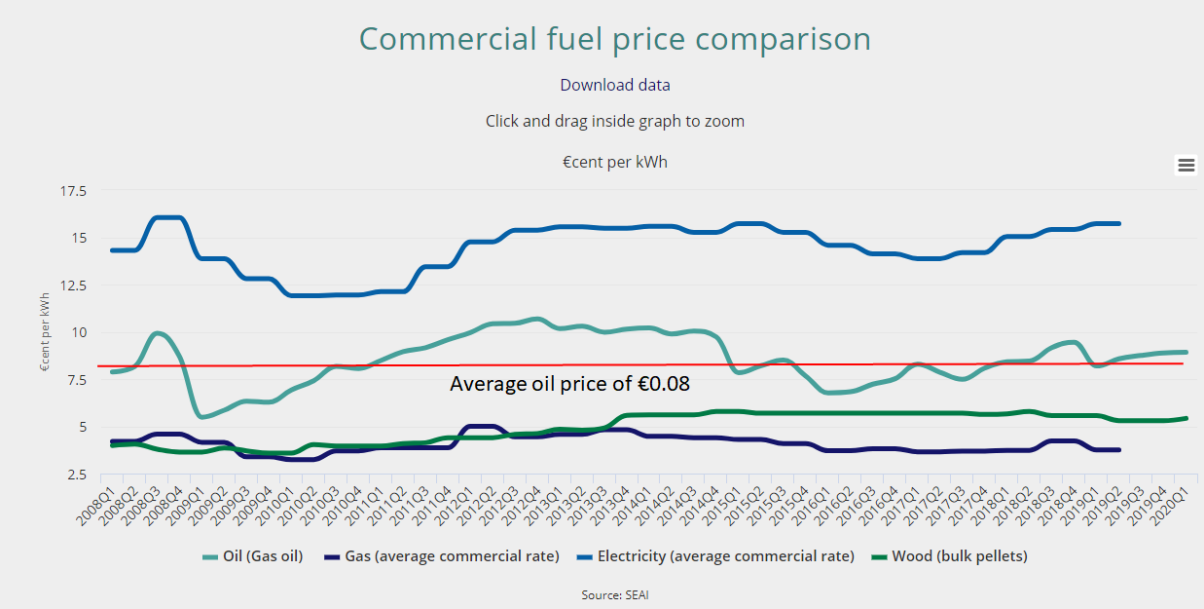
Table 2. Estimated supply chain costs. (1 tonne of 15%MC = 4,200 kWh & excluding own labour and CAPEX

Operation	€/tonne at 15% MC
Paid to farmer	37.77
Harvesting	20.70
Delivery to drying depot	18.90
Drying Costs	18.90

Supply Chain Considerations

- Fuel properties of supplied material
- Storage and its effect on fuel quality
- Boiler type destination
- What cost elements of the supply chain will the supply chain absorb?
- Funding mechanisms (grants / SSRH)

Transportation to boiler	8.00
Total	104.27
Cost / kWh	**0.025**



Ref. https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/prices/

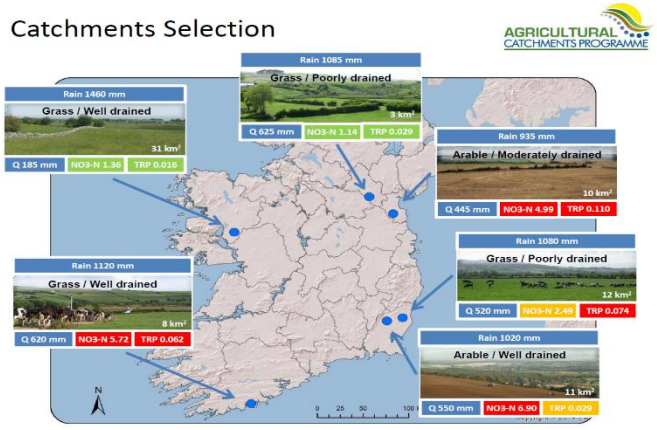
5.8. Catchment potential/opportunities - Eddie Burgess, Agricultural Catchments Programme Manager, Teagasc

Catchments vary in environmental footprint with reference to runoff. NO3-N & TRP. Based on ***Source -> Mobilisation -> Transfer -> Delivery -> Impact***

Dunleer - Arable land on moderately drained soils (mixed). High P due to **Source**, Mobilisation & Transfer.

Timoleague - Grassland on well drained soils. High P due to high Fe so Source, **Mobilisation** & Transfer.

Ballcanew - Grassland on poorly drained soils. Flashy hydrology so Mobilisation & **Transfer**.



- Ballycanew had poorest water quality (mean)
    - Surface driven & point source P losses & Cumulative loading along stream length.
- Timoleague had the highest P concentration.
    - Consistent levels along the stream (mostly) & Diffuse, ground water fed source of P
- Castledockrell had the lowest P across the stream.
    - Soil binds P and is free draining & Point sources an issue.

P highest in summer > autumn > Spring
Risk of significant P loss during winter rain events (Two days of winter storms, on bare and saturated soils, resulted in a total P loss equal to the annual average loss).

- In 4/6 catchments there was a 3 to 12% decline in index 4 (excessive P) soils over an 8-year period.
- 2 catchments had a 1 to 4% increase after a 4-year period.
- However: >50% of the area in all catchments continue to be suboptimal for soil test P (i.e., P index 1 and 2).
- On-going requirement for improved distribution of nutrients sources within and between farms across all catchments.
- These results are representative of national soil trends.
- Higher P loss from poorly drained soils.
- Nitrate spike in water after drought

Summary of ACP Water Quality – Dependent on Soil Type, Weather & Farm Practices

- Ecological status main driver for WFD
    - Constant trickle vs. big flush out Soil Type
- Nitrogen and Phosphorous contrast significantly
    - Where they come from
    - How they are carried

- Where they have an impact Farm
- Soil type, Weather and Farm practice all influence quality
- Point sources are still a significant issue.
  - Easy to identify and fix but social factors?

5.9. Nature Based Wastewater Treatment Systems - Opportunities & Challenges - *Mark O'Callaghan, Business Lead - Innovation, Standards and Technology, Irish Water*

1. Drivers for Nature Based Solutions are a number of EU "Megatrends" such as …

- Climate Change and environmental degradation
- Aggravating resource scarcity
- Growing consumerism
- Increasing influence of new governing systems

2. These can be aligned to current opportunities & challenges.

- Distributed Assets- Local Solutions
  - Assets closer to demand
  - Local Resources to feed Local Demand
  - Commercial, legal, regulatory, policy, planning, technical and risk constraints.
- Multi Use Infrastructure
  - Linear adoption model no longer appropriate
  - Integrated delivery of Infrastructure
  - Challenge of multi-agency integration
- Closed systems moving towards resource efficiency and zero waste
  - Managing leakage of resource to waste stream.
  - Recognising natural systems are incredibly efficient.
  - Use of wastes as feedstock in an integrated manner
  - Closed systems that could be carbon neutral.

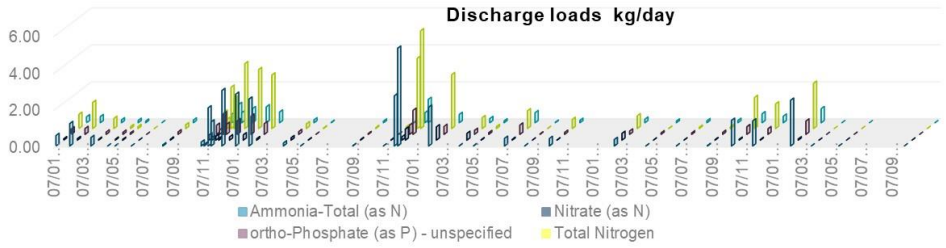
3. What are the Local Drivers?

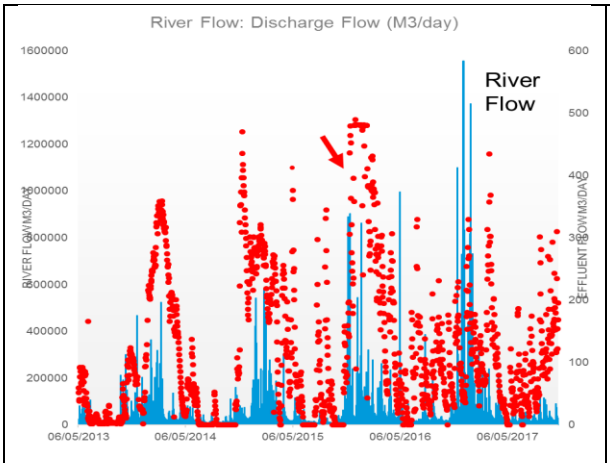
- Decline in water quality as a driver.
  - Pressure to increase quality of discharges, particularly from smaller WWTPS discharging into smaller and sensitive watercourses.
- Increasing cost of conventional approaches
  - Disproportionate cost impact of increasing standards on plants discharging to smaller watercourses and need for resilient and robust solutions.
- Public Sentiment
  - Alignment with public and institutional momentum towards, green solutions- 6 Capitals, EU Green Deal, Sustainability agenda.
- Maturity as an enabler
  - Critical mass of NBS plants, evolved design approaches, operations experience and research capacity and activity internationally.

4. What we might address to enable Nature Based Solutions (NBS)

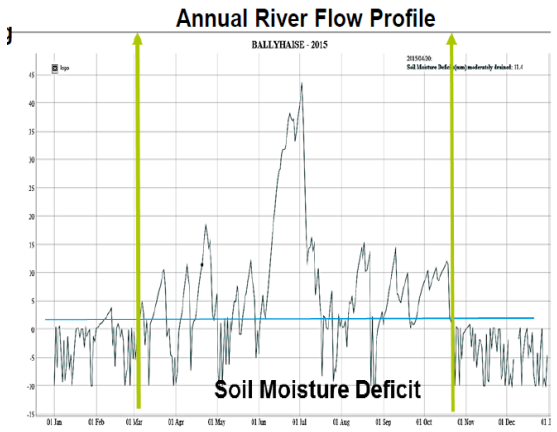
"Living solutions inspired by, continuously supported by and using Nature designed to address various societal challenges in a resource efficient and adaptable manner and to provide simultaneously economic, social and environmental benefits (EU)"

- Understanding they are different, treatment levels vary in response to seasons, climate etc. but so too does receptor capacity. Regulation based on grey infrastructure focused on end of pipe constrains NBS.
- Desirable outcomes: co-ordinating policy and legislation and tools to enable better holistic outcomes aligning with Green Agenda.
- Precautionary Principle: getting risk /gain balance right in accelerating delivery if it makes sense.
- Inertia: Learning, adaptability, co-operation and collaboration
- Valuing and benefits framework to account for all sectoral benefits and cross-sectoral funding mechanism to reflect this.
- NBS is not a panacea, suitable in some locations, how do we determine where?
- Knowledge base deficit, developing understanding across sectors, societal awareness, capacity to design and deliver.
- They are dynamic and roles and impacts change over time.





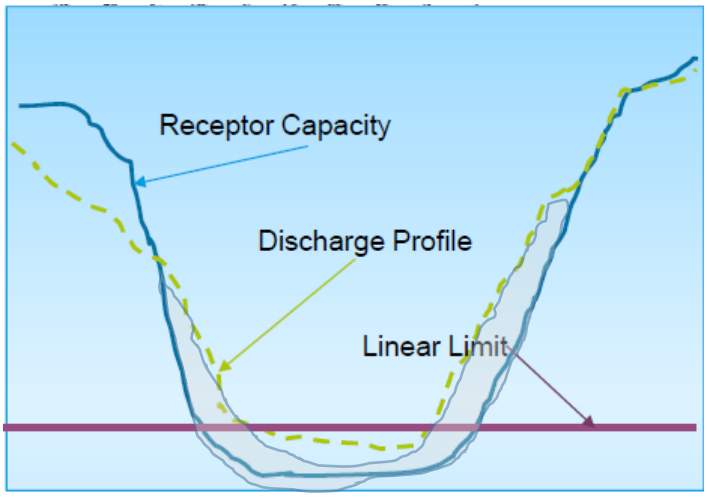
Discharge / River flow mapping



Annual River Flow Profile

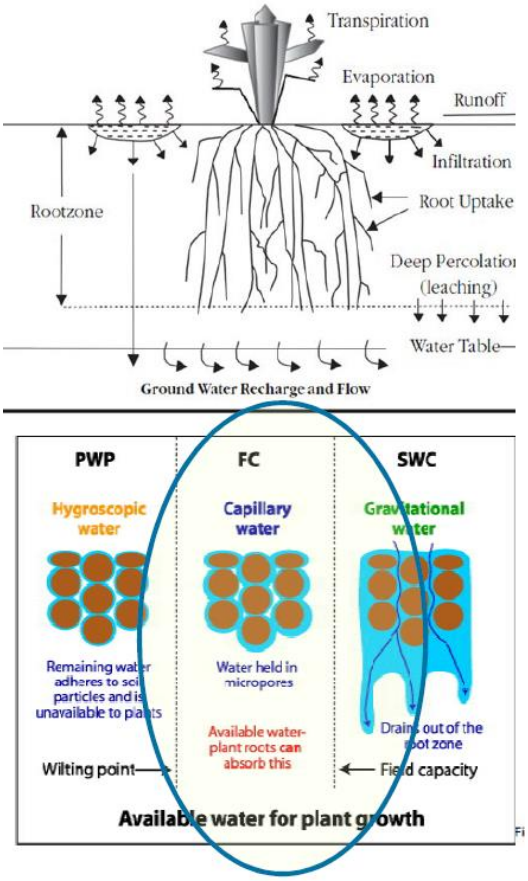
5. Opportunity for Seasonal Discharge / (Ref. NI – Variable Discharge Consent)

Receptor capacity tends to reduce through spring, summer & early autumn (reduced rainfall, lower flows, increased light and heat and resulting increase in potential microbial growth and BOD oxidation resulting in lower dissolved oxygen and deterioration of ecosystem.
Discharge profile would follow this trend to a degree however this is an opportunity therefore to inter-link, land-based treatment taking the pressure off the receptor.



6. Nature Based solutions

- Effective capacity for irrigation will depend on soil characteristics and Soil Moisture Deficit (Measured).
- Evapotranspiration rates will relate to type of vegetation cover, daylight, wind and solar intensity. (Measurable).
- Operating principle effectively managing the capillary water storage to maintain equilibrium between applied effluent, rainfall and evapotranspiration.
- Discharge to groundwater where treated effluent migrates to surface water.
- Water Table levels (hydraulic gradient), and groundwater quality will be directly monitored.



5.10. Multifunctional Benefits of Willow Crops - Kevin Lindegaard, Director, Crops for Energy Ltd

Willows also have several environmentally friendly uses. They are used for erosion control of riverbanks and coastal areas, in water treatment systems and for the bioremediation of sites polluted with heavy metals. In recent years farmers in many northern countries (such as Sweden, UK and Ireland) have begun growing willows as an arable crop to provide wood chip for biomass energy production. Such initiatives will provide an alternative to fossil fuels and enable us to reduce our greenhouse gas emissions. In the BioWill project we are harnessing the high yield and straight growth of willows bred for biomass as the base material for testing for new sources of salicins.
Willows thrive with wildlife. Pollarded willows which are so familiar in east England, Belgium, Holland and Northern France support whole plant and animal communities in their canopies. They are second only to oak trees in the number of insect species they support. For instance, there are about 100 species of butterflies and moths that rely on willow during their life cycle. Willow catkins are amongst the first flowers to bloom in February and March and provide bees with early sources of pollen and nectar.

Biodiversity Benefits – farms & the landscape

- Wild bird populations have fallen significantly since 1970
- 59 species of birds have Biodiversity Action Plans
- But significantly more birds in SRC willows compared to the improved grassland and arable controls.
- 12 bird species that reside in SRC willows with Biodiversity Actions Plans (BAPs) (Bullfinch, Corn Bunting, Dunnock, Lapwing, Linnet, Reed Bunting, Skylark, Song Thrush, Tree Sparrow, Willow Tit, Willow Warbler, Yellow Hammer)
- Pollination services (different willow varieties pollinate at different times thus increasing the period of nectar opportunity for pollinators.

Flood mitigation

SRC willows serve to mitigate flooding through a number of means …

- Significant water use
- Greater hydraulic roughness
- Enhances sediment retention (less need for dredging)
- Slows down the flow of flood water by acting as green leaky dams.
- Increasing the time available for issuing flood warnings
- Stops dangerous large objects and debris travelling downstream .
- Willow species can tolerate up to 13 weeks immersion without affecting growth and 1-3 weeks submersion.

6. Questions and Answers session with the expert panel of speakers.

This included interactive Q&A, live audience polls using Slido : Facilitated by Prof. Alistair McCracken who is a well-known figure in the research and development of SRC willow and related planted diseases as a result of a long career with The N.Ireland Department of Agriculture and subsequently the Agri-food and Biosciences Institute.

The following questions were put forward using the "Slido App" during the conference. Due to the extensive presentations and subsequent commentary between the conference facilitator (Professor Alistair McCracken) and a number of the presenters, time was short and therefore the answers were published on the website. This was then communicated to all registrants

Updated 12th March 2020

Question text	Answer
Is there any scheme similar further south?	Colecott Cottages in Fingal is a zero discharge plant which incorporates willow. Developed as a Pilot Project between Fingal Co Co. and TUD. There is also a plant in Donore Co Wicklow that deals with Primary effluent. I am not clear as to its current operational status. The ACP is working in a very similar way with regard to monitoring water quality, but to date, the ACP focus is on evaluating the Nitrates regulations in place, and not looking into additional mitigation measures. I.e. The ACP has not trailed additional mitigations actions, such as willow plantations.
Does the EPA measure presence of PFAS in domestic water?	There is currently no legal requirement to monitor for per- and poly-fluoroalkyl substances (PFAS) in drinking water in Ireland, because these parameters are not listed in the current drinking water regulations – the European Union (Drinking Water) Regulations 2014, as amended. However, agreement has been reached at European level on a new Drinking Water Directive which includes PFAS as new types of chemicals to be monitored in drinking water. In relation to PFAS, the new Directive covers a list of 20 substances (in Annex III) under the parameter "Sum of PFAS" with a parametric value of 0.1 ug/l. When the new Directive enters into force (likely to be during mid to late 2022), water suppliers will be required to monitor for these parameters in drinking water supplies and the EPA will have responsibility for ensuring compliance with those requirements for public water supplies.

At the site at Burt, where effluent is disposed, do you conduct soil analysis - is there any evidence of an increase in heavy metals in the soil ?	Yes, soil analyses are conducted and no evidence of HM build-ups. HM levels in effluent are very low and willow bio accumulates HMs such as Cd & Zn. The EU sludge Use in Agriculture Regulations (for land application of sewage sludge, which naturally would contain some HMs although not much given the absence of heavy industry in this region) control the application of HMs in agriculture. At Bridgend we are talking about primary and secondary treated wastewater, not sludge.
How many livestock animals are there on the island of Ireland? How does this relate to the number of humans?	For NI, Here are the data https://www.daera-ni.gov.uk/publications/farm-animal-population-data. There was a total of 6.9 million cattle on 111,300 farms in Ireland, giving an average herd size of 62 cattle. Over 60% of the cattle were located in 52,700 farms in the SE region, where the average herd size was 81 cattle. The Population of Ireland North and South is 6.5million. More cattle than people! https://www.cso.ie/en/releasesandpublications/er/lsd/livestocksurveydecember2018/
Will there be planning approval granted or Is there funding available for the use of reed beds, wetlands and willows for single house wastewater treatment.	This is an issue for Local Authorities who are guided by EPA Code of Practice: Wastewater Treatment and Disposal Systems Serving Single Houses (p.e. < 10). Guidance gives information on Reed beds and wetlands and whilst it mentions Willows, no design guidance is provided.
What impact do poultry facilities have regarding greenhouse gas emissions?	Much of the CO2e that is generated from the poultry is primarily from the utilisation of fossil fuels. This may be from purchased electricity, propane use in stationary combustion units (such as furnaces) and diesel use in mobile combustion units such as tractors and generators. In the animal industry the consumption of plants (feed) by animals results in the division of the carbon into animal biomass (meat & eggs) , CO2 respired by animals and faecal deposition of carbon in utilised coproducts (manure).
18% drop of GHG by 2030 in the “other” section , what sections do they represent	Much of the CO2e that is generated from the poultry is primarily from the utilisation of fossil fuels. This may be from purchased electricity, propane use in stationary combustion units (such as furnaces) and diesel use in mobile combustion units such as tractors and generators. In the animal industry the consumption of plants (feed) by animals results in the division of the carbon into animal biomass (meat & eggs), CO2 respired by animals and faecal deposition of carbon in unutilised coproducts (manure.
Is there plans to develop a sustainable agriculture strategy in Ireland? If not would such a strategy be useful? the UK have	AgClimatise is being developed and a strategy will be in place from a Climate/Environment Perspective over the next number of months. It should be a very useful strategy to address GHG emissions

developed one to address ghg target	
For John. Why is the phosphorus input from humans greater than livestock when the nitrogen level is the complete opposite?	The footprint of farming across the Irish landscape is broader and N loss is higher. The relative input of N is exponentially higher than P so losses would reciprocate also.
Are there meaningful incentives in place for anaerobic digestion?	In NI the ROCs finished in 2017 so unless the AD unit was registered then, there if noting since.
Do the stock levels include poultry numbers? Do we know if we have sufficient suitable ground for land spreading all the organic fertiliser produced?	In NI, there is not sufficient ground for spreading organic wastes.
I am looking for outlets for sewage sludges nationally. Willow might suit per Chris presentation. Do any attendees have Willow or other and seeking feedstocks?	This is an approach that is widely adopted in Eastern Europe, Sweden and elsewhere (Inc. In N.Ireland in the past). An appropriate level of pre-treatment of sludge is normally prescribed prior to application to lands. A high degree of Quality Assurance would also be required. IW would have an interest in discussions around this.
Do colder temperatures affect willow functionality?	Yes, but depends how cold. The growth can slow to zero. In the context of wastewater/sludge application, temperature affects level of evapotranspiration and thus may impact on loading rate for effluent. It would also be likely that nitrification and denitrification activity in soil reduces as temperature reduces as microbial kinetics are generally impacted on by temperature. This may impact on allowable loading rates. Willow treatment has been deployed for effluent in Canada and a number of recent papers have been published relating to same which may be insightful. In Denmark domestic units include storage to address seasonality. https://www.researchgate.net/publication/323884220_Willows_for_environmental_projects_A_literature_review_of_results_on_evapotranspiration_rate_and_its_driving_factors_across_the_genus_Salix https://www.sciencedirect.com/science/article/abs/pii/S0925857419300485?via%3Dihub
What happens to surfactants in water treatment works using willows?	Willow is generally used for polishing effluent downstream of primary or secondary treatment; as such effluent benefits from upstream treatment prior to discharge to willow, which should mitigate presence of surfactants. Detergents can contain phosphorus which is a plant nutrient.
For a landfill site generating approx. 35,000m3 of leachate annually, what area of willow	This will depend largely on the N concentration (high NH3) however this recycling route is not a currently licensed practice and any projects I am aware of are trials and proof of concept.

plantation would be required approximately?	
What happens with sludge from wastewater as it ant go through irrigation pipes to willow beds	Sludge is not applied through irrigation system. Where sludge is used, it is normally applied at the beginning of each rotation to provide nutrient to support growth over a 3-year cycle. Technically it can be applied annually using roll out hoses but I gather this practice is less common in Sweden where significant activity in this area occurs. The sites discussed at the conference are recycling / irrigating treated wastewaters and NOT the sludge. Any solids (ss) that might be present in the wastewater will either be taken out by the filter or if not, irrigated through the pipes and open irrigation pores (3mm to 4mm in size).
For Chris- have anyone looked at the impact of willow buffer zones on biodiversity particularly adjacent to aquatic habitats?	Yes, quite a lot of work has been done on this by QUB and other. Suggest contacting Kevin Lindegaard on this (reference his presentation at the event kevin@crops4energy.co.uk).
Chris' figures for Bridgend in 2019 don't add up- looks like 3-4 months when not irrigating willows. ICW is much better option for wastewater treatment	It's surely not about one nature-based system versus another. Willows provide a very versatile option for managing wastewaters while developing a circular economy via production of bio-resources. With reflection on Mark O'Callaghan's presentation (Irish Water), willows work synergistically with the climate and the environment, and this is a strong argument why such Nature Based Solutions could be implemented throughout the country. One of the key challenges for ICW's is seasonality of nutrient removal, particularly as they age. Significant decline in ICW P and N performance during winter months is evident, and P may be released back into effluent as vegetation decays. However, as receiving water flows are generally high during winter and riverine vegetation is dormant the impact on same would appear to be minimal. Winter P management could possibly be addressed by judicious addition of Alum Sludge from Water Treatment plants to ponds. (EPA Strive). Harvesting of Willow removes a quantity of the nutrients from the locus which does not generally occur with ICW's. Both systems depending on size may result in zero discharge during drier months when receiving waters are at their most sensitive to nutrients. Often the size of an ICW may be a barrier to its deployment due to land availability. In such cases initial polishing might be carried out in smaller ICW ponds with subsequent polishing in Willow. Ponds would offer buffer storage so that dosing could be controlled at sustainable rates to willows. Equally Willow offers a commercial return which may be more attractive to a landowner than outright

	sale of lands. Both systems have benefits depending on local circumstances, either individually or acting together.
For Chris - what % of NI Soils are Peaty?	14% of NI soils
Is there a future for willow on clay soils?	We have managed to establish willow in clay soils. It's not ideal but the willow growth does then start to improve the soils with time. It takes time and careful management.
How much carbon will a Hectare of willow take in over a rotation vs the carbon intake of spruce per rotation	If a ha grows about 10 dry tonnes per year the as 50% of the biomass is C, this is 5 tonnes per year. Isabella quoted further soil sequestration of around 2 tonnes/ha/y
Willow harvesting. implications for soil structure and compaction using heavy machinery in winter, potentially increasing runoff and sedimentation	This hasn't really been an issue anywhere to date from our experience. We are only harvesting once every 3 years or so and there is the option to use smaller lighter machinery.
How long is a rotation of willow	For energy purposes this has generally been every 3 or 4 years.
Stop start, boom and bust policies don't work, the sector needs structured long-term support via both environmental legislation and financial supports.	A third input could be wastewater effluent. Evidence suggests that up to 35% higher yield can result; primarily related to provision of water during summer where growth potential is highest, but often constrained by limited availability of soil water. There are also benefits in context of fertigation and possibly soil improvement depending on nature of effluent. Notionally a "gate fee" might also be put on the table.
Can willow to actively reduce ammonia discharging directly to a watercourse or is the ammonia just converted to nitrates by the passage of time?	The willow does actively reduce the discharge of ammonia. This is very apparent when experimenting with high NH3 effluents such as landfill leachates. The NH3 will be nitrified in the soils however it can also be used directly by the plant. Plants absorb ammonium and nitrate during the assimilation process. In case of wastewater, if TN is used as part of the design criteria then effective ammonia removal can be achieved from a Primary effluent. Ammonia in secondary effluents would generally be lower than that in Primary effluents.
What happens to effluent in the non-growing season and how long can this be for?	Willow plantations are generally used for polishing of treated effluent. During non-growing season effluent would receive normal treatment, and where capacity exists in Willow plantation to absorb effluent (non-saturated); part of load may continue to discharge to plantation with balance discharging to receiving water. The extent to which this might apply would depend on the size of plantation relative to hydraulic load at WWTP, soil characteristics and weather. Technically could be managed through monitoring of Soil moisture deficit or rainfall accumulation and/or intensity. Certain sites currently have all round licenses for application. Soil microbial processes still continue.

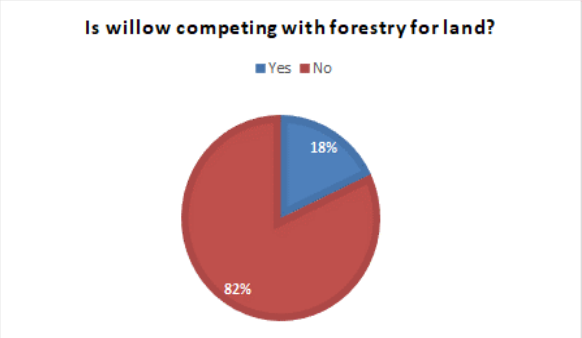
What is the most potentially polluting effluent you can use?	Leachates can be quite night in N and Cl. Some agri-food processing effluents can be very high in BOD. Farms effluents can be very high in P.
Is there a way to use willow to deal with excess slurry issues?	It will be looked at as the same as any other agricultural crop. I.e. 170kg N and nutrient according to crop requirement.
How many acres of willow required to remove 1ton of carbon	If a ha grows about 10 dry tonnes per year the as 50% of the biomass is C, this is 5 tonnes per year. Isabella quoted further soil sequestration of around 2 tonnes/ha/y
How do you make willow more attractive than forestry or leasing?	We need to develop a market for it…
What happens to the ash resulting from willow burning?	Potentially could be used as a fertiliser or element of compost. Generally, this goes out on the land again replacing the nutrients removed during its growth.
Is there a future for willow on gley soils?	We have managed to establish willow in gley soils - in the Fermanagh region for example. It's not ideal but the willow growth does then start to improve the soils with time.
How is nitrogen use on Willow governed?	By the Nitrates Directive and interpreted regionally. In NI the Nitrates Action Programme 2015-2018 and Phosphorus Regulations
To Dr Burgess: what was the name of the monitoring system that you used at your main monitoring location at Dunleer? I.e. the equipment used	If a ha grows about 10 dry tonnes per year the as 50% of the biomass is C, this is 5 tonnes per year. Isabella quoted further soil sequestration of around 2 tonnes/ha/y
In the ACP catchments how do the results compare to EPA Catchments monitoring in these waterbodies? Could these sub catchments be included in a RBMP priority area?	The ACP catchments are smaller than the EPA water bodies, and we only monitor six catchments, vs. 2355 in the latest Water Quality report. However, we take a sample every 10 minutes, vs. at most 5 per year in the EPA's monitoring. Currently only one of the ACP catchments is in a Priority Area for Action. The objectives of the PAA and the ACP are not the same, so it is not surprising that they don't overlap. It is hoped that the processes that impact on water quality established by the ACP's high resolution monitoring in a small number of catchments can lead to a better understanding of what is happening in the large number of water bodies being monitored (at a lower frequency) by the EPA.
For Eddie. Should controls on nutrient additions to land be catchment / soil specific rather than a general N loading max and closed periods?	A very simple answer to this is probably "yes", as our findings show that different catchments behave very differently, and "one size does not fit all" when regulating for good water quality. Some areas are Nitrate risky and others are not, but if nitrates are not lost to water there may be "pollution swapping" and gaseous emissions could be more significant where losses to water are small. The ACP results do support the "closed Period" as a disproportionately high load of nutrient leaves catchments during this period.

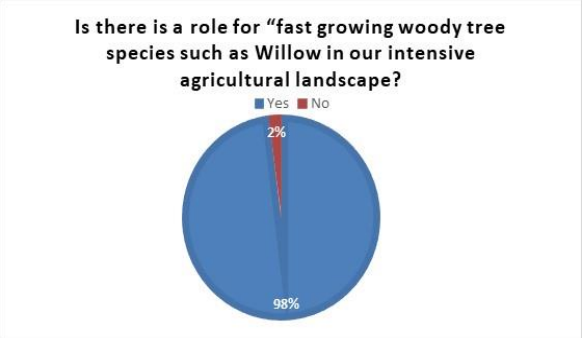
Has the catchments study examined the impact or potential of the different organic status of soil's on nutrients	None of the six ACP areas are located in high organic matter (peat) soils and soil organic matter contents do not vary much (generally 6 to 10 %). While all six catchments are located on intensively farmed mineral soils, we have undertaken research on organic & inorganic manures response on different soil types, where soil OM is one of many factors being considered.
Is there any consideration of the emission of methane from wetlands specifically reed beds?	There is a large body of research on methane emissions from Reed beds, primarily in context of natural and restored wetlands with less data available on ICW and Engineered Reed beds. As a rule, Carbon availability and low water depth minimises anaerobic activity and methane emissions. As ICW will generally meet both these criteria, emissions are likely to be lower than generally reported for wetlands. In case of reed beds at small plants the surface area is small in that generally they are used to polish effluent and as such have minor impact on emissions. Fundamental issue is whether NBS solution is less carbon intensive in comparison with other available solutions over their lifecycle and the additional value put on ecosystem services provided by same.
Re proposed seasonal discharge consents, surely the treatment process should be improved instead of exploiting the assimilative capacity of the receiving water?	It comes down to effective and efficient use of resources. Treatment using NBS confers multiple benefits vis a vis conventional system; Better outputs - Climate, Biodiversity, Social and Economic and less dis-benefits - Operational Carbon, visual intrusiveness etc. If a balance is to be struck then it is not unreasonable to leverage available natural receptor capacity which varies seasonally, to maximise nett benefits, whilst still achieving a better water quality outcome. For example, a small plant discharging to a small river in summer could impact significantly on water quality whilst a larger discharge during winter could have significantly lower impact. NBS are highly effective in attenuating pollutant load through reduced flow and incredibly effective removal of pollutants during growing season. The quid pro quo is that it is less so in winter but as nature tends to work in harmony winter, flows in rivers are generally a multiple of summer levels whilst biological receptors (algae and plants) are generally inactive. Nutrient are purged to a larger downstream water course and eventually the sea, where a significantly greater assimilative capacity may exist. Ultimately it comes down to how the cake is divided and the reality we find ourselves in - imagine being given the choice; we could build 5 Zero impact plants or 500 NBS, the latter giving significantly better benefits for society (environmental, economic, social)- which do you choose? It has been argued by some that the carbon cost of enhanced treatment may more than offset water quality benefits through negative carbon impacts and impact of iron panning in watercourses - LCS Studies in South Australia for example.

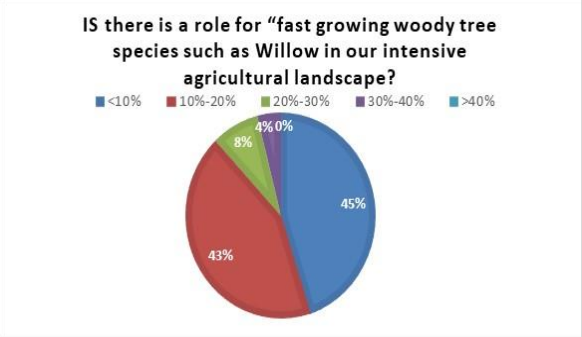
	As indicated, NBS is not a panacea and a case-by-case approach would have to apply. More importantly we need to adopt a holistic approach and perspective to maximise benefits we can accrue from limited resources without further depleting same. Looking at water in isolation of other pressures is becoming untenable.
Do you have to apply for planning permission to plant and harvest willow plantations?	This is an agricultural process so no.
Are there guidelines for establishing and managing willow plantations? Like Forest Service guidelines for forestry operations?	The AFBI / Teagasc Best practice guidelines were there at the Dundalk event. They are also at the following link.https://www.afbini.gov.uk/sites/afbini.gov.uk/files/publications/Short%20rotation%20coppice%20willow%20best%20practice%20guidlines.pdf
Most if not all previous entrepreneurs were let down and lost a lot of money. The public sector needs to provide guarantees and contracts on a large scale.	This is a comment.

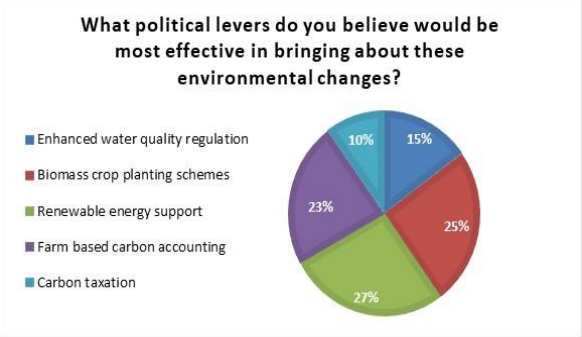
7. Conference Poll results

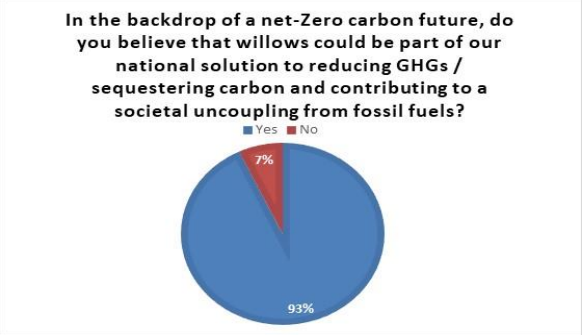
The following is a summary of the feedback of the responses to the questions answered in order to assess the stakeholders' views, understandings and interests to the implementation of SRC willows in our landscape. The graphs below illustrate specifically the feedback of the potential for Willows to play a part in several roles.

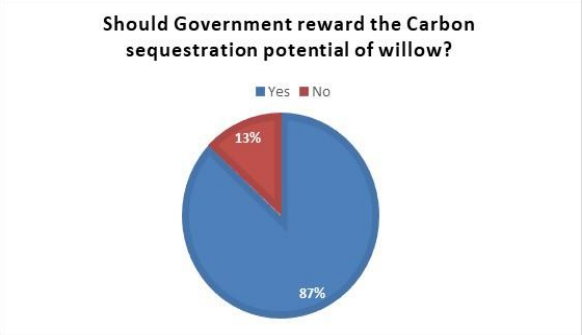


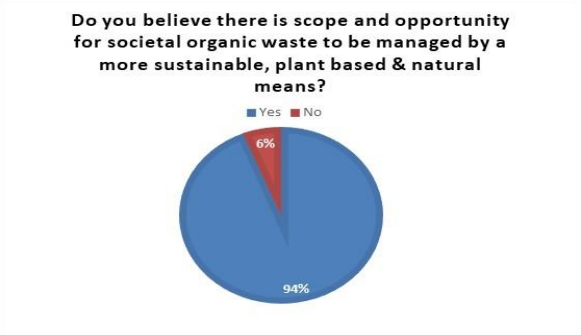




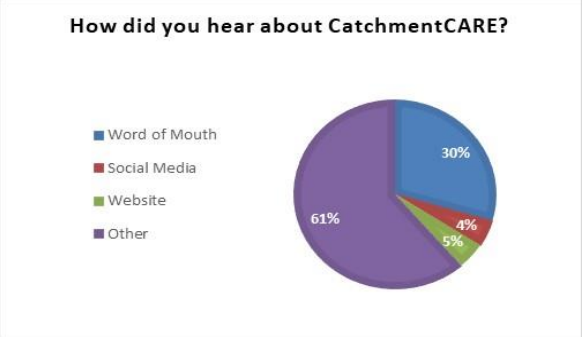


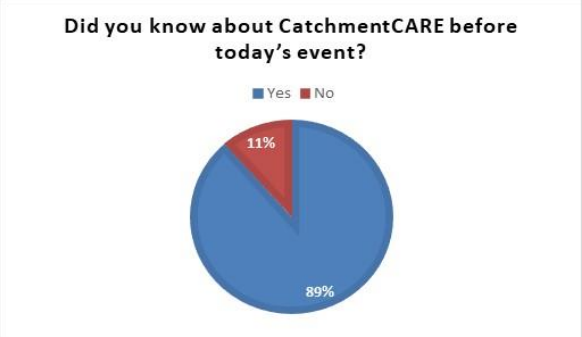


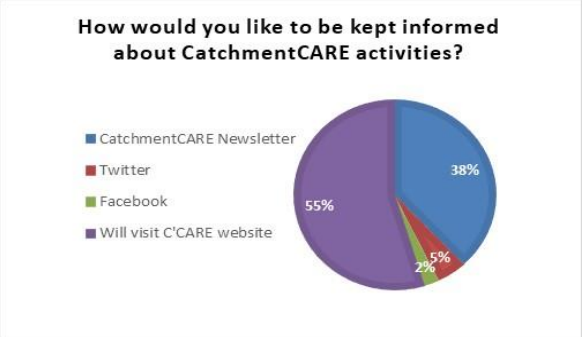


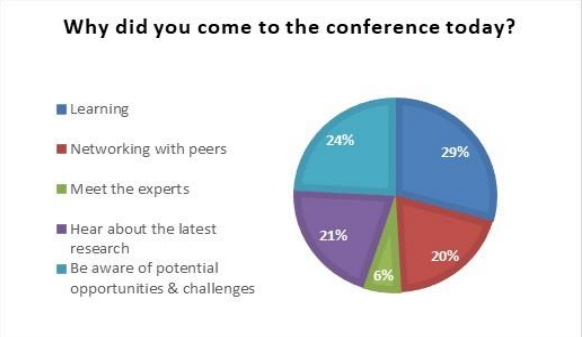


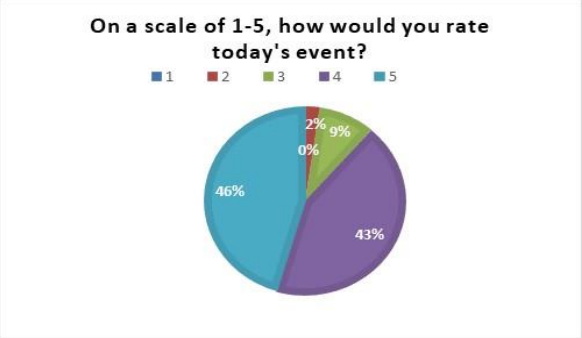
The graphs below illustrate specifically the feedback on the actual stakeholder conference.

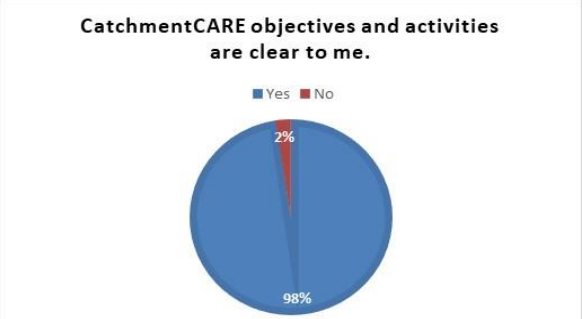












7.1. Open Text Responses.

- Very interesting topic...it is clear willow plays a major part in renewable energy, water quality and environmental protection. Keep up the good work and hopefully similar projects can be funded in the future.
- Immediate post conference 'speed dating' via an app would be useful. i.e. who you are, what you do, who you want to talk to. 10 min meeting request and booking slot.
- Very informative. Interesting to see the outcome in due course. Probably best for 'polishing' an effluent as compared to fully treat same.
- A very interesting and informative day. Great to hear about all the good work going on to try to develop this sector which has so many answers to the issues of today including climate emergency, failing environment, water quality protection fossil fuel and fossil product substitution and many others.
- Excellent informative day.
- Not at all convinced about the value of willows.

- Very useful event especially with regards to projects looking at improving water quality at a catchment level approach
- Questions after each session would be a better format.
- I'd have to give it a five as I was a presenter.
- Thanks to all the speakers.

8. Conclusion

Since about the 1970s, energy crops such as willow have been considered a viable option to provide some energy security where no fossil fuel reserves existed. This is most certainly true for N.Ireland and the Republic of Ireland. The need for a scale up in the production of these crops is arguably even more pronounced than ever especially considering recent 2020 and upcoming 2030 renewable energy targets and now international commitments to net zero carbon by 2050.

8.1 Recent sectoral stagnation

Unfortunately, over the decades government policies to develop and grow this sector have largely failed[7]. There are several possible reasons for this which include obstacles such as the strength of other agricultural sectors, the lack of biomass markets and processing infrastructure, embedded sectoral costs of producing biomass, short term incentivisation and scheme bureaucracy, failed large scale projects, competitiveness of large-scale biomass imports, low oil and other fossil fuel costs and potentially several others. Closer to home there has been the failed, and now terminated, NIRHI scheme which has left the biomass for heat sector disillusioned and upset. Furthermore, while progress is being made in terms of increasing renewable heat in RoI, Roi's performance in the use of renewable energy in the heat sector was a factor in not meeting the 2020 target. The SSRH continues to promote biomass for heating but anecdotally suffers from significant bureaucracy which may be a reason for the slow uptake of biomass heating.

8.2 Signs of Stakeholder Commitment

This conference, which included a wide range of stakeholders, clearly illustrates that there is a willingness and an understanding of the many and varied benefits which a move to a more sustainable agri-land use which includes biomass crops such as SRC willows, would deliver. Although there is a strong policy agenda to encourage the expansion of forestry, willow is not seen as competing with that land and this is most likely down to the fact that willow is an agricultural crop (EU definition) and as such it is supported under the common agricultural policy and allows a land-owner to switch to a different crop at a point in the future which would not be the case with forestry. There was almost unanimous agreement (98%) that there absolutely is a role for fast growing woody tree species such as src willow in our intensive agricultural landscape! This is a very pertinent point as it clearly opens up an opportunity for diversification of our intensive livestock agricultural system. A direction of change which will clearly benefit the environment in many respects but most notably in the areas of water quality and net GHG emissions.

[7] P.W.R.Adams, K.Lindegaard, A critical appraisal of the effectiveness of UK perennial energy crops policy since1990. Renewable and Sustainable Energy Reviews 55 (2016)188–202

8.3 Scale of adoption

This question was further clarified in regard to trying to quantify "to what extent" we might expect to see this kind of a conversion with almost 90% of respondents suggesting that it would likely be less than 20%. Recent recommendations from the UK Committee of Climate Change recommend to achieve approximately 700,000 ha of biomass crop land by 2050[8] and if this area was translated in terms of N.Ireland land area, it equates to approximately 3 to 4% of the land area which would be a significant increase in today's land devoted to biomass crops (approximately 900ha today to approximately 20,000ha, or indeed a further 120,000 ha in RoI). This level of integration of biomass crops would lead to a biomass sector of a respectful size (employment, infrastructure investment, machinery investment). 20,000 ha in N.Ireland, for example, would represent an energy value of over 1000 GWh, or almost 7% of N.Ireland heat requirement which is currently almost exclusively being supplied by fossil fuels (oil and natural gas). This land use change would also have a positive effect of the GHG emissions of the agriculture sector due to carbon sequestration and a biomass product which would displace fossil fuels (accompanied by water quality and biodiversity benefits).

8.4 Policy Options

Certain policy and incentivisation has been tried over the last 15 to 20 years and these have largely been targeted at the planting and establishment of biomass crops; names SRC willow in N.Ireland and both SRC willow and Miscanthus in RoI. These interventions essentially covered 40% to 50% of the costs of establishment, significant intervention which did lead to a level of Biomass crop establishment throughout the Island (estimated 5,000 ha). However, there was no industry to "pull" the crop's value through at the time meaning there was ultimately only one customer for miscanthus in RoI (Bord na Mona power station) and a number of biomass heat systems, North and South, using the SRC willow. The industry however wasn't thriving due in large part to less costly heating technologies and the relatively low cost of fossil fuels. The NI RHI was launched towards the end of 2012 however the biomass crops industry again did not really benefit from any pull due largely to the heat scale of incentivisation (99kW received the highest intervention rates and these heat systems were most likely to run on pelletised fuel – not SRC chopped willow or miscanthus).

However, the stakeholders at this conference recognised the many multifunctional benefits of biomass crops and suggested that several other attributes could be targeted for support. 25% of respondents agreed with past schemes asserting that further planting and establishment support will be necessary. This is understandable as this is the most costly step of entrance into the Biomass crops sector and therefore is likely to put off growers. Learning from previous failures, the largest group of respondents recognised that the renewable energies / technologies also required support given their disproportional purchase costs in comparison to oil or gas boilers. However, a total response of almost 50% of respondents suggested that policy could encourage the Biomass Crops sector by recognising and rewarding the Carbon, GHG

[8] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

and Water quality benefits provided by incorporating SRC willows in the agricultural Landscape. Furthermore, when asked specifically, nearly 90% of respondents felt that Biomass crop growers should be rewarded for the carbon sequestration activities. Solidifying these opinions further, 93% of respondents felt that a Biomass crops sector incorporating SRC willows had an important contribution to addressing a national solution to mitigate the rise in GHG emissions; essentially sequestering carbon and decoupling society from our dependence on fossil fuels.

8.5 Waste management and Recycling

As there had been considerable focus during the conference of how SRC willows could be used to not only protect the environment from diffuse runoff (EU CatchmentCARE Proof of Concept) but also point source discharges (EU CatchmentCARE Proof of Concept), the audience were also asked whether they thought there was a role for this type of application going forward. Even though these technologies are at an early stage of implementation, demonstrating and discussion for wider acceptance, it was encouraging to see that 94% of respondents felt that this is route worth pursuing. The land-based actions work Package in EU-CatchmentCARE has led to a lot more dialogue both North and South of the border (regulators & water utilities) through significant active working partnerships between Donegal County Council and AFBI. A “Case Study” document has been developed in order to enhance these discussions with the water utilities as seen in the Appendices.

Appendix 1 – Organisational Timeline

14th August 2019 (Dublin) – outline purpose and event content planning
10th September 2019 (VC) – further outline purpose and event content planning
24th September 2019 (Dublin) – outline purpose and event content planning
30th September (VC) bones of agenda developed (AFBI / DCC)
1st October (Email) -
4th October telecom with DCC
15th October (VC) – AFBI, DCC
25th October (VC) – AFBI, DCC
18th November (VC) – AFBI, DCC
29th November (VC) – AFBI, DCC, Mayo coco, Teagasc – scoping out the event with DD & CJ
9th December (VC) – beginning of contact list development.
6th January 2020 (Email) – further development of contact list with other CatchmentCARE partners
7th January – appointment of Conference facilitator
13th January 2020 (Dublin) – AFBI, Teagasc, DCC.
14th January 2020 (VC) – Agenda almost finalised
27th January 2020 (email) – agenda sent out to all speakers.
30th January 2020 (email) – first event reminder + agenda sent to all registrants.
4th February 2020 – 73 registered
7th February 2020 (VC) catch up with Teagasc, AFBI & DCC
10th February 2020 – Event request for publication on AFBI Website.
13th February 2020 – Photographer confirmed (in house)
13th February 2020 (email) – second event reminder + agenda sent to all registrants.
21st February 2020 (email) – third event reminder + agenda sent to all registrants.
4th March 2020 (email) – Event reminder and notification sent out by IrBEA – The Irish Bioenergy Association.
5th March 2020 – Event held.

Appendix 2 – Press Release of event

28/3/2020 – FARMING LIFE - "Willow plantations can contribute to a more sustainable environment" – CatchmentCARE Stakeholder event in Dundalk.
"https://farmweek.com/willow-plantations-can-contribute-to-more-sustainable-environment/"

Pictured (l to r) are: Barry Caslin (Teagasc), Con McLaughlin (Donegal County Council) & Chris Johnston (Agri-food & Biosciences Institute) at the CatchmentCARE "Willow Planting for Water Quality Protection" event in Dundalk on 5th March 2020.

PRESS RELEASE

Conference highlights how Willow plantations can contribute to a more sustainable environment.

With river catchments throughout Ireland suffering from increasing levels of pollution, a recent cross border seminar explored the benefits of using nature-based solutions for Water Quality Protection. The event, which was held at the Crowne Plaza Hotel, Dundalk last Thursday, 5th March 2020, explored the benefits of Short Rotation Coppice (SRC) willow planting and aimed to assess stakeholder interest & commitment to the principle of SRC and how this might fit with national strategies and address future environmental challenges.

The event was organised by Donegal County Council, the Agri-food and Biosciences Institute (AFBI) and Teagasc, as part of the EU-funded Interreg CatchmentCARE (Community Actions for Resilient Eco-systems) project.

The seminar explored Short Rotation Coppice via a number of information presentations, information polls and a questions and answers session. The event largely targeted those involved in policy, water, utilities, catchment management, energy, climate change & local authorities with an interest in exploring the potentials of using willows, mainly as landscape interventions and mitigation of runoff pollution but also how that can contribute to the sustainable energy, bioresources and climate change challenges.

The event was opened by Mr Michael McGarvey, Director of Services at Donegal County Council and the project introduced by Mr Con McLaughlin, EU CatchmentCARE Project Manager. A number of presentations were then given outlining the issue of Green House Gases in Agriculture and its role in meeting environmental objectives to set the scene.

The multifunctional benefits of willows have been a strong research focus area in recent decades and having worked in developing opportunities for sustainable wastewater management using willows, Chris Johnston, project leader at the Agri-food and Biosciences Institute in Northern Ireland (AFBI), then gave a flavour of some of the recent research and commercial schemes currently operating. Chris explained: “Catchments in the island of Ireland are suffering because of agricultural diffuse as well as societal point source pollution sources, so a conference exploring the potential benefits SRC willow could offer seemed timely. With a backdrop of striving for a net zero carbon future, it would seem opportune that nature-based solutions such as these, which can function synergistically with the climate & seasons, are seriously considered as part of the solution to mitigate against our current worsening environmental pressures.”

The event confirmed the understanding that biomass crops, if implemented properly in our agricultural landscape, can not only provide sustainable waste management and environmental protection, but can also contribute significantly to a more bio-diverse and net zero carbon future while underpinning rural biomass supply chains, agricultural diversification, and SME development & employment benefits.

For further details contact Chris Johnston (chris.johnston@afbini.gov.uk)

ENDS

Notes to Editor

CatchmentCARE (Community Actions for Resilient Eco-systems) is a €14m project funded under the European Union’s INTERREG VA Programme and aims to improve freshwater quality in river basins across three cross-border catchments. The aims will be achieved through the development of three water quality improvement projects in the **Finn**, **Blackwater** and **Arney** catchments and the installation of a new network of 50 groundwater monitoring stations across the region to better understand the interaction between groundwater and surface water bodies.

The project, which is 61 months in duration, has a partnership of eight from Ireland and Northern Ireland. Council partners include Donegal County Council (DCC) and Armagh City, Banbridge and

Craigavon Borough Council (ABC). Academic partners include Agri-Food & Biosciences Institute (AFBI) and Ulster University (UU). Specialist partners include Geological Survey of Ireland (GSI) and British Geological Survey (BGS). State agency partners include Inland Fisheries Ireland (IFI) and the Loughs Agency (LA). See more at http://www.catchmentcare.eu/.

The Special EU Programmes Body is a North/South Implementation Body sponsored by the Department of Finance and Personnel in Northern Ireland and the Department of Public Expenditure and Reform in Ireland. It is responsible for managing two EU Structural Funds Programmes, PEACE IV and INTERREG VA which are designed to enhance cross-border cooperation, promote reconciliation, and create a more peaceful and prosperous society.

The Programmes operate within a clearly defined area including Northern Ireland, the Border Region of Ireland and in the case of INTERREG VA, Western Scotland.

The INTERREG VA Programme has a value of €283 million and aims to address the economic and social problems which result from the existence of borders.

For more information on the SEUPB please visit www.seupb.eu

Appendix 3 – Further Press Release

The following was arranged and as a follow on to the SSRH Workshop and informed some of the preparatory work and ideas for the Stakeholders' conference ultimately held in February 2020.

FARMERS JOURNAL
Irish Farmers Journal | 03/08/2019

Media Source	Press	Page	54
Circulation	60,934		

Willow, nutrients and biomass heating in Co Down

Combined environmental demands could be met by planting willow crops in selected areas. **Thomas Hubert** reports on research by AFBI in Northern Ireland.

Both nutrient pressure on water quality and the need for biomass to replace heating oil may be addressed by one crop particularly suited to Irish growing conditions: willow. Northern Ireland's Agri-Food and Biosciences Institute (AFBI) has planted 5ha of the fast growing woody plant on its Hillsborough research farm in Co Down, under the EU-funded Waterpro project.

Part of this land includes a foot of grassland hill bordering a stream. Scientist Chris Johnston showed the *Irish Farmers Journal* six test plots there – three 14m x 10m areas planted with willows, three of which are interspersed where the original grass runs all the way down the hill. Planted three years ago and cut backonce, the plants are now taller than two people and some have woody trunks you can barely circle with one hand. Trenches dug across the bottom of the hill direct run-off water where its volume and nutrient loading is analysed at regular intervals.

"In time, we want to quantify whether the effect of the willow plantation actually has a positive response to the amount of nutrient and nutrient loading which could run off as a result of overland flow into our streams, rivers and lakes," said Johnston. Initial results show that this is happening, but several more years will be needed to obtain verified results – especially after the unusual weather observed in 2018.

Under another EU project, Catchment Care, AFBI is also measuring the effect of willow on water quality on a 20ha area on the farm. Johnston and his colleagues used Lidar technology to scan the land in 3D and identify where the terrain was most likely to cause water run-off: corners of fields, ditches and hollows on the hilly farm.

"We've used those areas to plant willow plantations into, with the theory to prove that in time, we will see a reduction in overland flow into these streams and environmental water supply," Johnston said. This is expected to occur as a result of the nutrient and water uptake of the willows, the rougher soil surface in the plantation and improved soil conductivity for water – "everything to try to prevent it running over land," he added. Equipment can be seen pumping water through the soil within the plantation to see how easily it percolates and measure such conductivity.

AFBI scientist Chirs Johnston shows a willow trial plot at Hillsborough.

> We've been using willow plantations, residues, brash forestry and energy crops to displace the use of fossil fuel

What is willow?

Willow (Salix spp.) is a fast-growing, woody plant capable of yielding 10tDM/ha/year under Irish growing conditions. It has a high water and nutrient demand, and 85% of its fine shallow root system is located within the 20cm top layer of the soil. It can be irrigated through piped systems with fluid effluents, such as dirty farmyard water or treated wastewater. A previous project involving AFBI successfully irrigated the effluent from the Bridgend wastewater treatment plant in Co Donegal, into a 6.3ha willow plantation on land provided by Donegal Creameries.

Willows can be harvested every two years by coppicing. It's chipped for biomass heating, then regrows from ground level. A plantation typically lasts 25 years.

From plant to fuel

The willows grown at Hillsborough are used to heat the farm and research centre, powering one of the three biomass boilers used at AFBI's bioenergy centre. "On-farm here, we've been using willow plantations, residues, brash forestry and energy crops to displace the use of fossil fuel," said Chris Johnston. "We distribute this around the farm in a 2.5km district heating system to the offices, the buildings, the dairy parlour."

Willows are usually harvested with a self-propelled silage harvester, but Johnston is looking into cheaper, PTO-powered harvesters for small areas planted selectively around the farm.

Some of the heat is used to dry the willow chip and other biomass fuels produced on the farm. Johnston reckons the cost of producing heating fuel from willow at Hillsborough is 1.5p/kWh. While this does not cover land costs or the profit a farmer would need to make to grow the crop commercially, it still compares very favourably with heating oil at current prices.

Johnston said that interest in the bioenergy research conducted by AFBI was lower in Northern Ireland now that the Renewable Heat Incentive (RHI) scheme has closed.

However, there are lessons to be learned for the Republic, where the Support Scheme for Renewable Heat has just opened to support users of biomass fuel.

Three-year-old willow plantation at AFBI Hillsborough.

Willow chip used as fuel at AFBI Hillsborough.

Trial plot to control nutrient run-off into water at AFBI Hillsborough.

Appendix 4 – Short Version Summary

(A) Introduction

Ireland is currently facing many competing economic & environmental pressures as a result of the following, many of which will continue to be compounded by climate change.

- increasing populations,
- intensifying agriculture,
- increasing pollution/degradation of air, water and soil,
- failing on environmental targets (i.e. to improve water quality and GHG & ammonia emissions),
- subsequent biodiversity decline,
- reliance on energy importation,
- pressures of fluctuating energy prices and this effect on society with reference to fuel poverty,
- requirement for low carbon renewable energy generation,
- increasing flooding concerns linked largely with climate change,

These pressures are demonstrated by increasing demands on public finances e.g. wastewater treatment upgrades (towns, villages, housing developments, septic tanks) and a strained farming model (small unprofitable farms). Many of these pressures are addressed in EU Directives and Ireland's environmental commitments and targets (Table 1).

Table 1. Environmental Commitments & Targets. DAFM 5/3/20

Climate	Air	Water	Biodiversity	Renewable Energy
GHG 10-15% reduction to 2030 Delivery 16.5-18.5MT CO_2eq cum. Abatement from 2021 to 2030	Target for NH_3 is 112kt by 2020 and 107kt by 2030	EPA report 2013-2018 further decline in water quality. Agriculture responsible for 53%	Agriculture & land use significantly impacts on biodiversity due to >80 of Ireland's UAA	2020 – 16% 2030 >16-32%

Furthermore, the Climate Action Plan 2019 identifies how Ireland will achieve its 2030 carbon emissions with Net Zero Carbon Emissions by 2050. **Action 60** effectively bans the installation of fossil fuel heating from 2022 (2025) in all new dwellings. Water quality challenges are clearly illustrated (Fig. 1) by the number of high status waterbodies decreasing while the number of poor status water bodies is increasing. This is because of both society but more so agriculture.

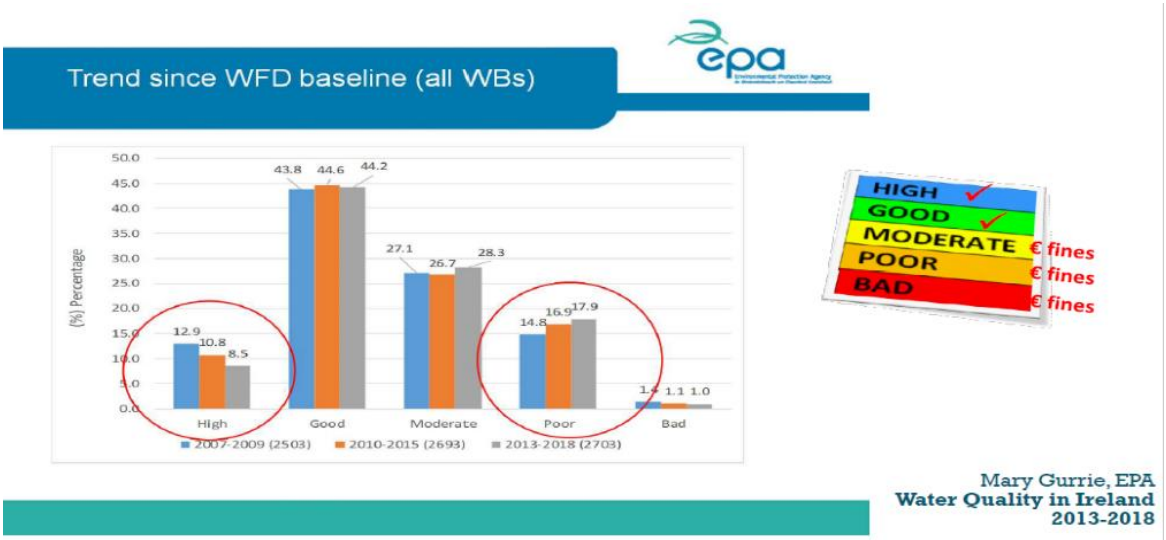


Fig. 1 Water Quality in Ireland. EPA 5/3/20

(B) Multi-functional benefits

Agricultural diversification to biomass crops such as willow can help address many of the environmental sustainability challenges and targets via the crop's multi-functionality…

- Climate - Fossil fuel substitute to reduce GHGs, carbon sequestration.
- Water & Bioremediation - Water quality protection
- Biodiversity - Improved Biodiversity and many related benefits
- Renewable Energy - Contribute to Renewable energy through bioenergy.
- Flood prevention - Adopted as 'natural flood retention measures' or slow the flow.
- Carbon sequestration - Modern carbon v ancient carbon
- Noise pollution, air, soil - Pollution protection
- Employment - Farming, processing, technology application

(C) Willows for water quality protection, wastewater management & phytoremediation

In 2007, DAERA in Northern Ireland funded an AFBI research & development project examining whether willow plantations could be used to bio/phyto-filter wastewaters from farmyards. The results have shown no indication of negative impacts with a high remediation of water and a substantial uptake in nutrients[9]. The knowledge, experience and interest which this project succeeded in developing gave rise to the successful bid for funding under the EU-Interreg lV programme and brought about the ANSWER project with the main partners of Donegal and Monaghan County Councils along with AFBI[10]. The ANSWER Project succeeded in the planting of over 100 acres of SRC willows for the dual purposes of wastewater management and the simultaneous production of bio-resources for bioenergy. Although at the time bioenergy was, and still is, the prime use of this bio-resource, there are other higher value uses which are currently being developed [2] [11]. Wastewater treatment works (WWTW) with marginally compliant discharges, as a result of infrastructure age and population increase, were adapted to irrigate the treated effluent to the willow plantations. One such site in Bridgend, County Donegal, has been running since 2014. This WWTW serves a population of approx. 650 people. Historically the treated wastewater was discharged into the adjoining Skeoge River however it is now largely irrigated onto 14ha of willows. The results from the 2014 summer period revealed an 85% reduction in discharge from the plant into the river (rising to 93% in 2018) during the growing season when the river is most often experiencing low flow. The willow crop has been harvested twice since establishment.

Over the last five years, over 50% of the treated wastewater has been recycled to the willows, on a yearly basis, with this level rising to over 80% when the summer months are viewed specifically (**Fig. 2**). Generally, during the summer months rainfall is less, receiving water flow is lower, light and heat availability are higher and as a result the receiving water body is most vulnerable to pollution, eutrophication and ecological deterioration. Maximum benefit can be derived by discharging to the willow crop during this period as conversely, this is when the willow will have a high evapotranspiration rate, protect soil & ground water but also have high nutrient assimilation potential for N & P encouraging maximum yields.

The use of willows for waste management and phyto / bioremediation, as well as the greening and cleaning up of contaminated sites, can aid in the uptake of plant macronutrients but also the removal and bioaccumulation of heavy metals such as Cadmium, Copper, Nickel & Zinc which will result in the combustion ash if used for bioenergy[12].

Irish Water are charged with improving discharges from public wastewater systems. 45% (555No) of WWTW serve a population less than 500 PE and 63% are under 1000PE. Over half of these require, or are likely to require, upgrading

[9] Edward G.A. Forbes, Christopher R. Johnston*, John E. Archer, Alistair R. McCracken, SRC willow as a bioremediation medium for a dairy farm effluent with high pollution potential, Biomass and Bioenergy 105 (2017) 174e189.
[10] https://www.afbini.gov.uk/articles/bioremediation-projects#toc-1
[11] https://www.nweurope.eu/projects/project-search/biowill/
[12] Ange Nzihoua,∗, Brian Stanmoreb The fate of heavy metals during combustion and gasification of contaminated biomass—A brief review. Journal of hazardous materials

due to the lack of historic investment as focus has been on larger agglomerations under UWWD. This illustrates a real opportunity to replicate the case at Bridgend which would seem applicable given …

- That the locations need robust and resilient solutions.
- The need to be able to address highly variable flows and sometimes loads.
- The cheapest CAPEX solution rarely the best in context of value and new Green Framework

The implementation of natural treatment solutions would bring about the many multifunctional benefits listed above.

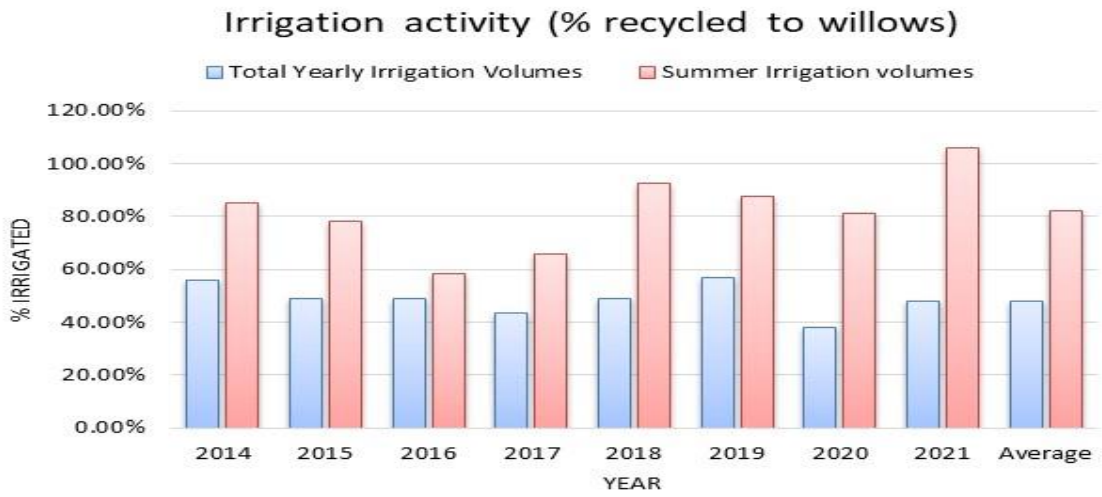


Fig. 2 Wastewater Irrigation data from Bridgend WWTW – Co Donegal

A similar logic would also apply for willows placed in the landscape, to interrupt pathways of hydrological connectivity, for water body protection of diffuse run-off (Fig.3). Even though willows will carry out an overland flow impedance function with surface roughness, increased percolation, drainage and water & nutrient uptake through the year; it is during the summer months that livestock is grazing and slurry & dirty water are being spread on land. As such, with increasing rainfall events (frequency & intensity) as a result of climate change, riparian biofiltration blocks can mitigate

run-off as a targeted effect to protect rivers and lakes.

Fig. 3 Biofiltration block protecting waterway from diffuse pollution. (Activities ongoing within EU-CatchmentCARE are demonstrating the extent to which these effects can be realised)

(D) Biodiversity Benefits – farms & the landscape

In England where far more significant willow planting has occurred, the following data has been collected and indeed it is suggested that the following red and amber listed species can be found in and around SRC willow[13]:

- Wild bird populations have fallen significantly since 1970.
- 59 species of birds have Biodiversity Action Plans
- But significantly more birds in SRC willows compared to the improved grassland and arable controls.
- Red listed Lapwing, Willow tit, Skylark, Song thrush, Tree sparrow, Yellow wagtail, Linnet, Yellowhammer, Corn bunting
- Amber listed Stock dove, Willow warbler, Dunnock, Bullfinch, Reed Bunting
- Pollination services (different willow varieties pollinate at different times thus increasing the period of nectar opportunity for pollinators.

(E) Flood mitigation

SRC willows serve to mitigate flooding through a number of means …

- Significant water use
- Greater hydraulic roughness
- Enhances sediment retention (less need for dredging)
- Slows down the flow of flood water by acting as green leaky dams.
- Increasing the time available for issuing flood warnings
- Stops dangerous large objects and debris travelling downstream.
- Willow species can tolerate up to 13 weeks immersion without affecting growth and 1-3 weeks submersion.

(F) Supply Chain and crop Value (bioenergy)

Arising from the recent launch of the Support Scheme for Renewable Heat[14] (SSRH) there is now the opportunity for a growing market for bioenergy. SRC willow provides an opportunity to fulfil a part of this market (alongside traditional private and public forestry). There are many ways to look at the value of such a supply chain i.e. from the grower's perspective as an own-use fossil fuel replacement or a supplied commodity. Along with the SSRH, these supply chains could significantly address renewable energy and GHG reduction targets and desires while giving a diversified financial return for farming. In essence, 1 tonne of dry wood chip would realise approximately 5000 kWh energy. At an average heating oil price of €0.08/kWh[15], this would value the crop at €400/dry tonne or €3,600/ha/y based on a direct kWh comparison value! Naturally however, there are very many agricultural, processing, labour & haulage costs to consider as with any other agricultural product. So, supply chains could be aligned as below.

Table 2. Estimated supply chain costs. (1 tonne of 15%MC = 4,200 kWh & excluding own labour and CAPEX

Operation	€/tonne at 15% MC
Paid to farmer	37.77
Harvesting	20.70
Delivery to drying depot	18.90
Drying Costs	18.90
Transportation to boiler	8.00
Total	104.27
Cost / kWh	**0.025**

Supply Chain Considerations

- Fuel properties of supplied material
- Storage and its effect on fuel quality
- Boiler type destination
- What cost elements of the supply chain will the supply chain absorb?
- Funding mechanisms (grants / SSRH)

In the past it has been difficult to motivate farmers to grow SRC however the Support Scheme for Renewable Heat[16] (SSRH) creates the opportunity ("the market pull") across the country rather than in just in one place. Allowing for

[13] https://www.rspb.org.uk/globalassets/downloads/documents/birds-and-wildlife/birds-of-conservation-concern-4--the-population-status-of-birds-in-the-united-kingdom-channel-islands-and-the-isle-of-man.pdf
[14] https://www.seai.ie/publications/SSRH-Grant-Scheme-Operating-Rules-and-Guidelines.pdf
[15] https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/prices/
[16] https://www.seai.ie/publications/SSRH-Grant-Scheme-Operating-Rules-and-Guidelines.pdf

good yields and economies of scale (harvesting, transport etc.) and selling into heat markets it should be possible to achieve a net return of €400 per hectare per year basing figures on yields of 12 tonnes (15% MC) per hectare per year, €130+ per tonne sale value.

(G) Conclusion

The leadership role which public bodies can play in taking early action is fundamental to achieving our de-carbonisation goals. As we evolve towards a more complex sustainability & resource perspective with multiple higher-level goals, it is important we look at multiple sectors and multiple policy perspectives. Wastewater thus becomes a source of fertilisation, woodchip becomes a bio-economy feedstock, willow becomes a land diversification option and all this together addresses the many sustainability targets we must achieve. The fact that SRC willow can bring so many widespread benefits to agriculture, environment and society must surely raise the question as to whether we should be implementing a strategic plan to facilitate the planting of this versatile crop.

Bridgend WwTW Willow biofiltration System

Proof of Concept & Demonstration

Contents

1. Aim

To assess the practicalities and effectiveness of woody bio-filtration blocks in managing nutrients from point sources – through collecting data from a well-established Proof of Concept site with SRC willow bio-filtration plantations.

2. Introduction

Irish Water is responsible for improving discharges from public wastewater systems. 45% (555 No.) of wastewater treatment works (WWTW) serve a population of less than 500 Personal Equivalents (PE) and 63% are under 1,000 PE. Over half of these are likely to require upgrading due to a lack of historic investment, as recent focus has been on larger agglomerations under the Urban WasteWater Directive (UWWD).

A commercial scale effluent irrigation schemes was established at Bridgend, Co. Donegal, Ireland (55o 2' N: 7o 22' W). The Willow Biofiltration project came about as a result of the EU-Interreg lV programme's ANSWER project with the main partners being Donegal and Monaghan County Councils along with AFBI. The ANSWER Project succeeded in the planting of over 100 acres of SRC willows for the dual purposes of wastewater management and the simultaneous production of bio-resources. Although at the time bioenergy was, and still is, the prime use of this bio-resource, there are other higher value uses which are currently being developed. Wastewater treatment works (WwTW) with marginally compliant discharges, because of infrastructure age and population increase, were adapted to irrigate the treated effluent to the willow plantations. One such site in Bridgend, County Donegal, has been running since 2014. This WWTW serves a population of approx. 650 people. Historically the treated wastewater was discharged into the adjoining Skeoge River however it is now largely irrigated onto 14ha of willows. The willow plantation is irrigated with dirty water and continues to efficiently manage the loadings applied and in doing so strongly illustrates a circular bioeconomy whereby waste "nutrient" is used to fertilise a biomass crop.

A real opportunity exists to replicate the wastewater management solution at Bridgend given …

- The locations need robust and resilient solutions,
- The need to be able to address highly variable flows and sometimes loads,
- The least expensive capital expenditure solution is rarely the best in the context of value and the new Green framework.
- The drive for a net zero Carbon (C) 2050

3. Bridgend findings and data

Seven years' data from Bridgend currently illustrates that approximately 50% of the inflow into the Bridgend WwTw is irrigated to the SRC willow. However, during the summer months, this figure increases to an average of 80% over the last 7 years (**Fig 1**). The monthly data from 2019 is seen in **Fig 2** to illustrate the monthly variance. It is during these months where there is a higher chance of chemical and ecological decline in the receiving waterway as a result of nutrient input due to lower

rainfall, lower dilution, higher light and heat. This would therefore seem to indicate that the implementation of SRC willows for wastewater management can work very well in tandem with current WwTW and in doing so, they represent a low CAPEX, low Opex, low Energy/carbon solution for point source pollution management. These types of Nature Based solutions also provide a myriad of biodiversity benefits and other non-market co-benefits.

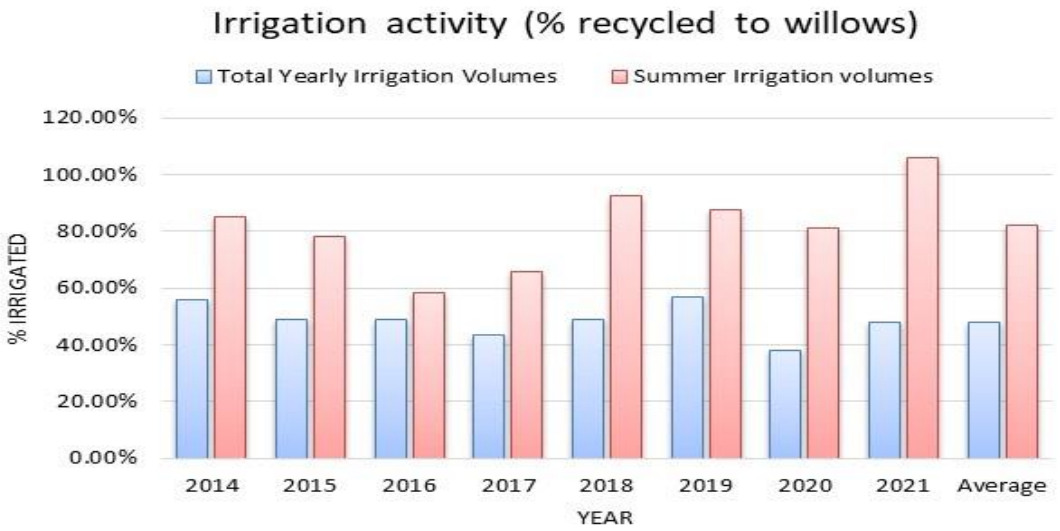


Fig 1. % of wastewater recycled from inflow over 7 consecutive years

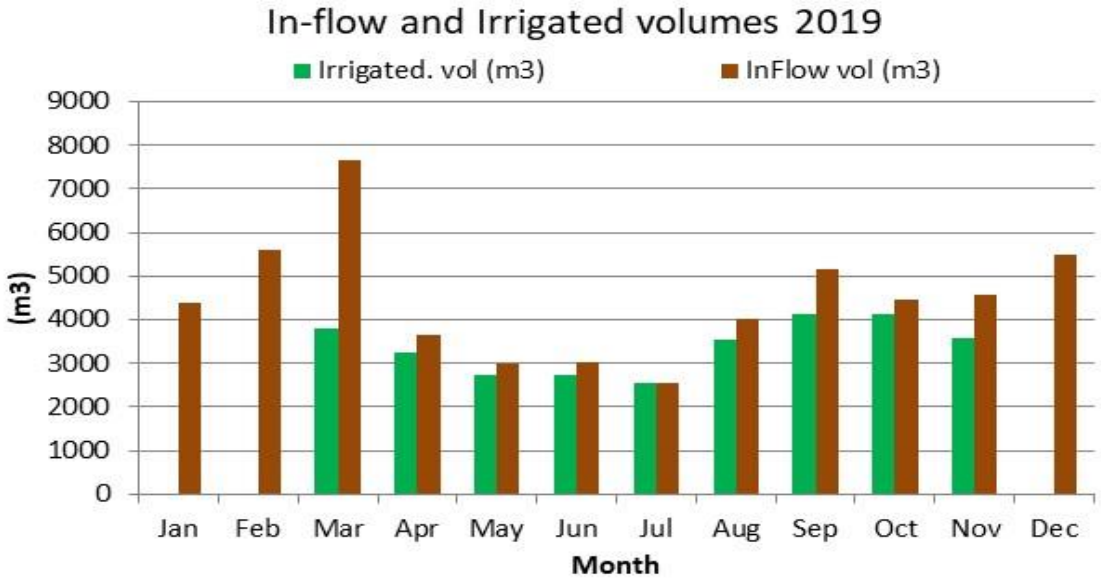


Fig 2. Irrigation pattern during 2019.

This rate of application over the years is calculated from the WwTW discharge quality (**Table 1**) to be approximately that outlined in **Table 2**. According to the Teagasc/AFBI nutrient guidance[17], these levels of nutrient application are well within the nutrient guidance recommendations and therefore present an opportunity to increase the rate at which nitrogen and phosphorus could be applied. The guidance recommends up to 180 kg N/ha/year and 24 kg P/ha/year while currently the Bridgend

[17] https://www.teagasc.ie/media/website/publications/2011/Short_Rotation_Coppice_Best_Practice_Guidelines .pdf

system is receiving an estimated 67 kg N/ha/year and 3 kg P/ha/year. It would seem therefore there is a lot of scope for further sustainable nutrient recycling to the 14 ha of SRC will coppice.

Table 1 – Average Discharge Effluent (reference data from Donegal County Council

Parameter	Bridgend (mg/l)
NH_3-N	10.6
Total-N	31.6
Total-P	1.5
ss	50.0
BOD	22.4
COD	93.0
pH	7.3

Table 2.- Estimated mass of recycled nutrient

Discharge from June 2014 to end June 2021

	Inflow to WWTW	Irrigated to willows	Discharge to Environment	Loading per ha per y
Volume (m^3)	432,320	206,829	225,491	2110
Total N (kg)	13,661	6,536	7,126	67
Total P (kg)	636	304	331	3

4. Towards a net Zero carbon future

4.1. Sources of carbon saving

It is considered that willow nature-based systems such as these contribute towards a reduced C economy in the following ways…

a. The crop grows yearly fixing CO_2 into the above ground biomass.
b. The crop sequesters C in the soil as part of the root/leaf litter development and creation and maintenance of a thriving soil microbial ecosystem.
c. The biomass is harvested and used in fossil fuel displacement.
d. The plantation is used to manage / treat wastewater substituting energy demand at the treatment works (pumps / aeration / chemicals).

Since the willow was established, 2014, treated wastewater has been irrigated to this plantation. The yearly volumes irrigated to the crops is summarized in Table 2. To the end of June 2021, this was 207,000 m^3 which is approximately 2,100 m^3/ha/year. Furthermore, it is estimated that the willow plantation has received the equivalent nutrient loading (Table 2), for biomass crop fertilization. The alternative would have been that this mass of nutrient was discharged to the aquatic environment, adding to water quality decline.

4.2. Harvest

The site has been harvested twice; once in 2017 and once in 2019. The biomass harvested is summarized in Table 5. Only fields 1 and 2 have been harvested to date due to diminished access into field 3. Standing, unharvested Biomass is also estimated.

Table 5: Biomass production, Harvested and standing Biomass

Year	**Field**	**Area planted** (ha)	**Harvest** (Tonnes)	**Yield** (t/ha/y)
Harvest (1) 2017	1	6.3	254	13.4
	2	4	161	13.4
	3	3.3	0	0.0
Harvest (2) 2019	1	6.3	248	15.7
	2	4	157	15.7
	3	3.3	0	0.0
Standing 2020	1	6.3	91.8	
(based on average	2	4	58.3	
yield)	3	3.3	288.4	

Total Biomass harvested	819 tonnes FM
Total Biomass Standing	439 tonnes FM
Average %MC	54%

Total Biomass	579 tonnes DM
Total C	= 283 tonnes (*C = 489g/kg dm)*[18]
Total CO_{2e}	**= 1037 tonnes**

4.3. Fossil Fuel displacement (to date over 7 years)

Instead of the C being accounted for as fixed in biomass, this biomass can be processed and used to displace fossil fuel use. Heating oil has a CO_2 emission of 0.245 kg per kWh[19]. 541 tonnes of dry woodchip is an estimated 2,700 MWh so indicative of a saving of **665 tonnes of CO_{2e}**

4.4. Wastewater treatment (to date over 7 years)

There are several estimates for how much energy is used in a wastewater treatment plant such as 45 kWh per PE per year for a treatment works of about 10,000. Bridgend is much smaller than that (approx. 650) however this would be the equivalent of 29,250 kWh / year. In 2019, Ireland grid power had a C intensity of 0.325 kg of CO_2e per kWh of electricity. The willow plantation has been taking approximately half the wastewater produced on an annual basis for 7 years.

Total Yearly CO_2e emissions saved = 9,506 kg CO_2e / year x 0.5 (1/2 volume treated)

Over 7 years CO_2e emissions saved =33 tonnes of CO_2e

Other metrics exist such as energy use in wastewater is 67kWh/PE[20]. A WwTW the size of Bridgend (650PE) would therefore require …

Total energy used per year based on average 67kWh/PE = 43,550 kWh (€0.14/kWh = €6,100 /year)

Total Yearly CO_2e emissions saved … = 14,154 kg CO_2e / year x 0.5 (1/2 volume treated)

Over 7 years CO_2e emissions saved =50 tonnes of CO_2e

4.5. Carbon sequestration by SRC willow crops (to date over 7 years)

Evidence from recent studies across the UK show that growing SRC willow on suitable agricultural land can have multiple benefits improving economic viability and the delivery of key ecosystem services (e.g., increased C sequestration and high yields; Milner et al. 2016). A two year-long study conducted in the south of England shows that SRC willow is a net C sink approximately sequestering 6 tonnes C /ha/y (Harris et al. 2017). Even when C was removed as harvested products, SRC willow remained a net sink of 2.2 tonnes C ha/y. Findings from these studies suggest that changes from grassland to SRC willow ultimately has several environmental benefits.

7 years of sequestration on 14ha SRC willow = 216 tonnes C

7 years of sequestration on 14ha SRC willow = 792 tonnes CO_2e

[18] E.G.A. Forbes, D.L. Easson, G.A. Lyons, W.C. McRoberts. Physico-chemical characteristics of eight different biomass fuels and comparison of combustion and emission results in a small scale multi-fuel boiler. Energy Conversion and Management 87 (2014) 1162–1169

[19] DEFRA (2007) Act on CO2 Calculator: Public Trial Version Data, Methodology and Assumptions Paper www.defra.gov.uk or www.carbonindependent.org/files/actonco2-calc-methodology.pdf

[20] NIWater personal communications). Average

3.3.3 Deliverable: An assessment of stakeholder commitment to the principle of SRC willow planting and how this fits with national strategies.

4.6. Summary of carbon savings over the 7 years of Bridgend operation

Saving source	**Tonnes CO_{2e}**
Biomass harvested	1037
Sequestered	792
Fossil fuel GHG displacement	665
Wastewater treatment Energy displacement	50

5. Conclusion

The growth and utilisation of a SRC willow plantations for the combined purpose of generation of bio-resources/biofuels and management of wastewater has many environmental benefits. A future net zero carbon society will need every low carbon tool available. The treatment of wastewater using SRC willows has been proven to work at the Bridgend, Co Donegal site and as such it should be a priority now to build on this excellent Proof of Concept and Demonstration site as this technology represents a real opportunity for the water sector to demonstrably cut its carbon emissions.