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# The role of energy crops in effluent disposal, energy supply and soil remediation

## Key external stakeholders:

Farmers, local government, solid biofuel suppliers, consumers, policy makers, scientific community

## Practical implications for stakeholders:

- *Farmers* can benefit from the knowledge that the practice of applying organic wastes to energy crops should not cause damage to the environment. Additionally, farmers may take advantage of a lower cost method for drying willow chips.
- *Policy Makers* can now take into account that application of organic wastes to energy crops should not cause damage to the environment. Additionally, information on factors which influence the willingness of farmers to adopt energy crops can be used to structure future bioenergy incentives
- *Scientific Community* benefits from this project as new information is now available on the environmental risks associated with organic waste amendment to energy crops, on willow chip drying as well as on the economics of energy crops and the willingness of farmers to adopt energy crops.
- *Local Authorities* benefit from the knowledge that organic waste from wastewater treatment plants can be applied safely to energy crops.

## Main results:

- Sewage sludge application to energy crops should not lead to a build-up in soil pathogens provided the sludge is treated appropriately i.e. limed
- Losses of nutrients and heavy metals to surface water following application of organic wastes to energy crops were small in comparison to losses to groundwater yet losses to groundwater did not result in a deterioration in groundwater quality as groundwater threshold values were not exceeded with the exception of levels of phosphorus in plots which received the highest concentration of brewery effluent. No threshold values were exceeded when sewage sludge was applied to energy crops.
- Willow chips can be dried at a low cost by blowing ambient air through a clamp of chips covered by a breathable material at an airflow rate of 150 $m^3$/tonne wet chips for 12 hours a day.
- Willingness to adopt bioenergy crops was found to be significantly influenced by the agricultural educational level of farmers, farm size, and farm system. Biomass targets are more likely to be achieved when fixed prices are offered for biomass in comparison to variable prices.
- The uncertainty surrounding risky variables such as the costs of production, yield level, price per tonne and opportunity cost of land make it difficult to accurately calculate the returns for biomass crops. Simulations, however, show *Miscanthus* generally has higher certainty equivalents, and therefore farmers may be more likely to invest in *Miscanthus* rather than willow.

## Opportunity / Benefit:

This project has shown that energy crops can be used for safe disposal of organic wastes and this use increases the range of benefits offered by energy crops to stakeholders specifically as well as to the community in general. Additionally, the project has shown that willow chips can be dried in a farmyard at low cost, reducing the cost of drying willow chips should increase the attractiveness of this crop to farmers.

## Collaborating Institutions:

Carlow IT, University College Dublin



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## 1. Project background:

Energy crops have many attractions as sources of secure, locally-produced and locally-used renewable energy. At the same time disposal options for organic wastes are becoming more limited as restrictions tighten on organic waste entry to land-fills and animal health concerns are restricting their application on pasture. Municipal sewage sludge volumes may be expected to increase as new treatment plants come on stream.

The use of local energy crop plantations for the disposal of suitable municipal and food industry wastes could benefit local authorities and local waste-generating industries as well as farmers and energy users. Energy crops could also provide a productive and restorative use for contaminated land that is unsuitable for food or feed production. Various aspects of these possibilities have been researched in several countries with generally favourable results.

Yet commercial uptake of energy crops to date has been slow. The energy crops that have shown most promise in Ireland to date are willows and *Miscanthus*. Both are high-yielding crops suited to the Irish climate and which could be used for bioremediation (disposal of organic waste). If this combined energy/waste disposal concept is to develop, a number of issues have to be addressed:

- For regulatory agencies, assurance is needed that the effluents are applied to the sites in a way that does not lead to any pollution of air or water, or create any health hazard for humans or wild life inhabiting the site.
- For heat users, practical systems for drying harvested biomass must be developed and demonstrated.
- For land-owners considering the establishment of energy crop, their investment must be shown to be profitable in comparison with traditional enterprises.

The project was designed to address these issues.

## 2. Questions addressed by the project:

- Are microbial pathogens a problem after sewage sludge is applied to energy crops?
- Does water quality suffer due to losses of nutrients and heavy metals after application of organic effluents to energy crops?
- Is it possible to develop a low-cost system for drying willow chips?
- What are the economic returns to farmers from growing biomass crops and what is the likely uptake of energy crops among farmers?

## 3. The experimental studies:

Sewage sludge and brewery effluents were applied to existing willow and *Miscanthus* plantations. Concentrations of nutrients and heavy metals in groundwater, overland flow, soil and plant biomass were measured. The objective of these measurements was to determine the fate of nutrients and heavy metals in organic wastes applied to bioenergy crops. Measurements were also conducted to determine the fate of pathogens in municipal solid waste applied to bioenergy crops.
Systems for drying of willow chips were examined with a view to identifying a low-cost system and determining drying cost.

Crop production , harvesting, storage/drying and utilisation costs were determined for willow and *Miscanthus* and the value of the fuel produced was estimated. A net present value model of energy crop profitability was constructed and stochastic modelling was used to determine the level of risk from different energy crop options. A survey was conducted of farmers willingness to adopt bioenergy crops.

## 4. Main results:



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**Microbial Pathogens in Soil after Application of Sewage Sludge to Energy Crops**

- The sufficiency of liming of the sewage sludge prior to application was found to be important as it was found that biosolids with a lower pH allowed for the survival of *E.coli* and for the transfer of this pathogen to soil.
- Based on the data gathered and analysed over 3 years, sewage sludge application should not be followed by a build-up of soil pathogens provided the sludge is treated appropriately i.e. limed

**Loss of Nutrients and Heavy Metals to Water after Application of Sewage Sludge to Energy Crops**

- For Phosphorus, Potassium, Copper and Zinc, there was a clear relationship between the quantity of organic waste applied and the mean concentrations of these elements in groundwater. For nitrate, chromium, cadmium, nickel, lead and zinc there was no clear relationship between the quantity of waste applied and the mean concentration of these elements in groundwater.
- For surface water, there was a relationship between the quantity of organic waste applied and the concentrations and total exports of nitrate, potassium, phosphorus, chromium, lead, cadmium, copper and zinc in surface run-off (overland flow). There was no clear relationship between the quantity of effluent applied and the levels of lead or nickel occurring in surface run-off.
- Losses of nutrients and heavy metals to surface water in overland flow events were small due to the fact that overland flow events were relatively rare and typically involved small volumes of water. Losses to surface water were small in comparison to losses to groundwater yet losses to groundwater did not result in a deterioration in groundwater quality as groundwater threshold values were not exceeded with the exception of levels of phosphorus in plots which received the highest concentration of brewery effluent. No groundwater threshold values were exceeded when sewage sludge was applied to energy crops.

**Development of a low-cost system for Drying Willow Chips**

- It is possible to dry willow chips at low-cost by blowing ambient air through a clamp of chips constructed in a farmyard. In this system a single phase fan blows air through a pipe with holes along its length, a border for the clamp can be constructed using pallets and the clamp should be covered by a material through which air can pass. Air is blown through the clamp for 12 hours a day at an airflow rate equivalent to 150 $m^3$/hr/wet tonne. The final trial was conducted during the summer of 2008 when, in spite of the wet summer, the chips in the pile dried from 52% at the start of the experiment (April) to 18.2% (July) over an 82 day period. 617 units of electricity were used to dry the chips which represented an electricity cost of just under €5 per wet tonne.

**The economics of biomass production at farm level**

- The uncertainty surrounding risky variables such as the costs of production, yield level, price per tonne and opportunity cost of land make it difficult to accurately calculate the returns to biomass crops. A stochastic budgeting model was developed to estimate distributions of returns from willow and *Miscanthus*. The results of these simulations show *Miscanthus* generally has higher certainty equivalents, and therefore farmers may be more likely to invest in *Miscanthus* rather than willow.
- Willingness to adopt bioenergy crops in Ireland was significantly influenced by the agricultural educational level of farmers but also by farm size, and farm system.
- A target of 30 percent substitution of biomass for peat in the three peat fired power stations from 2015 has been set by the Irish Government. In order to achieve the target, approximately 40,000 hectares of biomass crops will need to be planted. A policy mechanism of a fixed price has a large



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effect on the economic returns from biomass crops, and therefore on the level of adoption. The target area could be achieved at a fixed price per tonne of €70 and €65 for willow and *Miscanthus* respectively. This is compared to the current prices for willow and *Miscanthus* of €55 and €60 per tonne, which were not fixed and therefore subject to year on year variation.

## 5. Opportunity/Benefit:

Energy crop cultivation offers a number of potential benefits which include import substitution and greenhouse gas mitigation in addition to offering an alternative enterprise for farmers. This project has shown that energy crops can be used for safe disposal of organic wastes and this use increases the range of benefits offered by energy crops to stakeholders specifically as well as to the community in general. Additionally, the project has shown that willow chips can be dried in a farmyard at low cost, reducing the cost of drying willow chips should increase the attractiveness of this crop to farmers. Thus, the project has increased the utility and attractiveness of energy crops. This benefit is available to all stakeholders.

## 6. Dissemination:

This research was presented as part of an MSc and two PhD theses in conjunction with UCD.

### Main publications

Clancy, D., Breen, J, Butler, A.M. and Thorne, F. (2009). A Discounted Cash Flow Analysis of Financial Returns from Biomass Crops in Ireland. Journal of Farm Management Volume 13, No. 9, pp. 595 -611

Clancy, D., Breen, J, Moran, B., Thorne, F. and Wallace, M (2011). Examining the socio-economic factors affecting willingness to adopt bioenergy crops. Journal of International Farm Management Vol.5. Ed.4 - June 2011 ISSN 1816-2495

Galbally P, Fagan C, Ryan D, Finnan J, Grant J and MacDonnell K (2012) Journal of Environmental Quality 41, 1-10.

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