Extended Abstract
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Paper/Poster Title	**A Bio-Economic Model analysis of producing silage as a feedstock for Anaerobic Digestion in Ireland**

Abstract prepared for presentation at the 97th Annual Conference of the Agricultural Economics Society, The University of Warwick, United Kingdom

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Abstract *200 words max*

The economic case for the production of silage for Anaerobic Digestion (AD) can only be established by analysis of the potential costs at farm level. This paper uses farm level data from Ireland in a bio-economic modelling framework to provide total costs per hectare for production of silage for an off farm AD facility.

Whilst perennial rye grass has traditionally been the sward of choice for livestock farmers in Ireland, the economics of a multi-cut nitrogen fixing crop such as red clover has been relatively unknown.

The results from the simulated bio-economic model show that the total costs of production silage for AD has increased significantly in the past twenty four months. The modelled cost of Red-Clover based silage has increased from €135 to €200 per tonne harvested between 2018-2020 to 2022, an increase of 48%.

The results also highlighted the importance of accounting for the opportunity cost of nutrient content of digestate which increased from €370 to €907 between 2018-2020 and 2022. This opportunity cost of nutrients in the digestate accounted for 21% of total costs of silage production. Furthermore an 11% cost saving can be made while reducing overall GHG emissions by utilising digestate in a separate farm enterprise.

Keywords	Anaerobic Digestion, Bioenergy, Biomethane
JEL Code	e.g. Energy: Demand and Supply Q41 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction *100 – 250 words*

The use of grass silage for AD is considered a second generation biofuel and is a renewable alternative to fossil fuels, which has the potential to reduce Green House Gas (GHG) emissions particularly when codigested with animal slurries. Agriculture is responsible for 33% of GHG emissions in Ireland and has made commitments as part of our national Climate Action Plan (CAP) to reduced agriculture related GNG emissions by 25% by 2030.

Agriculture in Ireland is dominated by grassland accounting for over 90% of the utilizable agricultural area (UAA). The majority of this forage is utilized by grazing

animals during the growing season but there is a requirement to preserve silage for the winter housing period. Conversion of grassland to growing crops for AD would constitute a land use change and potentially increase carbon emissions due to release of soil carbon. Conversely, silage wouldn't cause any land use change and with existing knowledge and experience in the farming community reducing the perceived risk of adoption.

A bio economic flow model is used to examine the existing costs of producing silage in Ireland based on simulated data for a red clover sward. This data is compared to farm level data in period of 2018-2020 for tradition perennial ryegrass sward while the modelled production is used to evaluate the input price shocks that have occurred in early 2022.

Methodology	***100 – 250 words***

This paper used a simulated bio-economic model to facilitate the calculation of agricultural feedstock costs on a per hectare and dry matter yield basis for use in a regional AD plant. The model was used to quantify the cost of producing and utilising a red clover sward, for which historic data from our Teagasc, National Farm Survey Data was not available. Constructed data, from various sources were used to populate the bio-economic model.

The model is a spreadsheet-based, bio-economic simulation model, which includes input of physical and financial variables. It is based on a single year deterministic input framework, but is re-simulated under different annual conditions. Agronomic defaults in terms of field operations are based on various literature sources and output from the Grange Feed Cost Model (GFCM, Finneran et al., 2010). The economic input variables are based on annual input costs at prevailing 2020 - 2022 prices.

Results	***100 – 250 words***

The data from the bioeconomic model show that growing silage, from a red clover sward, for AD in Ireland has increased significantly over the past twenty four months. The modelled cost of Red-Clover based silage fertilised solely by digestate has increased from €135 per tonne harvested in 2018-2020 to €200 per tonne harvested in 2022, an increase of 48%. In addition, if synthetic fertiliser is used solely to replace nutrient off-takes the increase in the cost of production of silage is 65%.

The results also highlighted the importance of accounting for the opportunity cost of nutrient content of digestate, particularly in a high fertiliser price environment like 2022. The opportunity cost of the nutrient off take increased from €370 to €907 between 2018-2020 and 2022.

This opportunity cost of nutrients in the digestate accounted for 21% of total costs of silage production with a significant proportion of this value accounted for by nitrogen content, all of which is not required by the red-clover based sward, due to the

nitrogen fixing ability of the crop. The utilization of the digestate in another enterprise and replacing nutrients with synthetic fertilser would lead to a 11% cost saving as well and reduced GHG emissions of entire farming system.

Discussion and Conclusion	***100 – 250 words***

The economic case for growing silage for AD was evaluated using a total cost bio-economic modelling approach showing lower costs for production of a red-clover sward compared to a traditional perennial ryegrass sward.

Whilst this paper focuses on economic sustainability criterion, the adoption of AD could have additional environmental sustainability benefits to the agriculture industry, by reducing farm level GHG emissions and reducing dependency on artificial fertilisers. The use of digestate as a fertiliser could stimulate the circular bio-economy while reducing the GHG emissions from fertiliser manufacture and the needs for imports.

Finally, the socio-cultural elements also need to be evaluated in the context of a developing AD industry in Ireland. The potential to increase the productivity to supply AD while increasing the viability levels of original enterprises could potentially prove attractive.