BEIS

BIOMASS FEEDSTOCKS INNOVATION PROGRAMME

PHASE 1

Automated planting, weeding and harvesting of Miscanthus in harsh environments, exploiting complementary microalgal production for increased revenue options

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Final Report

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Introduction

Government objectives supported by the Climate Change Committee are to expand the energy crop production across the UK from about 7000 to 750 000 ha. Producing sustainable energy crops enables security of energy supply and opportunities to produce higher value products through exploiting biorefinery concepts. Miscanthus is a well-known energy crop with profitable yields. Recently, significant breeding programmes [1, 2] have developed new genetic varieties which allow expansion of Miscanthus farming into new harsher regions, where Miscanthus is not conventionally grown, allowing the UK to reach its growth targets. The West of Scotland does not generally produce crops because of its poor climate, however, new Miscanthus varieties opens new opportunities to exploit hitherto untapped land. The theoretical land area available in Scotland is 900 000 ha [3], with little consideration to the West of Scotland or lands not normally considered viable for crop production. Exploiting such regions, however, brings new challenges in adapting technology and methodologies to farm in these harsh environments.

Tractors are heavy and poor at working in harsh conditions, compacting soil and reducing land utilisation. Commercial, automated, state-of-the-art, clip on (to tractor) technology, has recently been demonstrated, capable of planting up to 5000 plants/hr. This leads to cost effective planting, which can be translated to Miscanthus production, using new strains, in harsh environments with an appropriate all-terrain vehicle. The utilisation and development of precision agricultural systems (PAS), coupled with a Land Robot, drones, sensors, and state-of-the-art communication systems, leads to robust methods to farm in colder and wetter climates, exploiting land that would otherwise not be used.

Developing the biomass supply chain is complex and takes time. Uptake from farmers and land owners can be encouraged through enabling mechanisms to develop forestry alternatives and adding value through the Miscanthus process chain, within the farm-gate, including systems to minimise farming effort and emissions. Efforts in automation of Miscanthus farming have been developed for planting and harvesting in what would be considered “easy conditions” over large areas. Such systems will likely fail in harsh environments generally due to their size, poor traction and uneven land. The project innovation is 1) Identify strategies to plant Miscanthus trials at Cochno Farm (a working farm owned by the University of Glasgow) under harsh conditions, 2) Develop integrated, robust drone and land based strategies for planting, weeding and harvesting 3) Provide added value to the farming cycle e.g. torrefaction and microalgal production.

Technology

To establish whether the fields at Cochno farm were viable for planting Miscanthus, three fields were initially identified for their suitability. Various factors were considered including their availability within the farm context, soil conditions and setting challenging tasks for the autonomous technology.

The soil was sampled in three fields to identify their suitability for planting Miscanthus. Figure 1 shows the soil sampling locations for three fields that satisfy the farm land utilisation strategy. Field 1 was sampled at three discrete locations (labelled 1, 2 and 3 in Figure 1), Field 2 at one point (4) and Field 3 at two locations (5, 6). The pH, K and soil type are noted in Figure 1. Whilst each field was suitable for Miscanthus planting, preference was given to field 1, primarily because it is more challenging than other fields, with aerial and land obstacles (HV cable, trees and rocks) and stepper gradients. Figure 2 shows a photograph of Field 1 and the overhead power cables and other obstacles can be seen.

Area	pH	K (ppm)	Soil type
1	4.8	283	Sandy Loam
2	4.8	275	Loamy Sand
3	4.7	162	Sandy Loam
4	5.6	187	Sandy Silt Loam
5	5.5	248	Sandy Loam
6	4.9	80	Sandy Loam

Figure 1 Soil sampling locations from Field ranked 1 (1, 2 and 3), Field 2 (4) and Field 3 (5, 6). pH, K and soil type (table, right)

Figure 2 Potential Field, Ranked 1, for Miscanthus farming (0.77 ha)

Clip on technology to plant Miscanthus in shown operating in the field in Figure 3, and methods to implement clip on technology within harsh environments is part of the wider deployment strategy in future work. The methodology for planting Miscanthus was determined and it was noted that the windows for planting and harvesting may be shifted compared to warmer climates.

Figure 3 Robotic clip on technology for planting

Phase 1 was constrained by time, but a simple, small AV was built, using extruded Aluminium simplifying construction, to identify in field manoeuvrability and impacts of soil compaction. An early prototype of the chassis is shown in Figure 4. From calculations, the likelihood of soil compaction is small, to mitigate this further with the addition of clip on technology, tank tracks were designed to distribute the weight and reduce pressure.

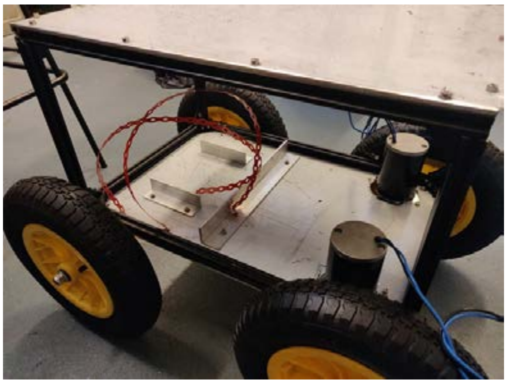

Figure 4 Early stage prototype for the AV chassis

As with many fields in rural locations, the network connectivity at Cochno farm is poor. The connectivity for each field (see Figure 1) was measured at its extremities, Figure 5 shows the upload and download speeds for each field and the GPS accuracy from a network connected mobile phone. Field 1 had the lowest upload speed which is another challenge for collecting in field data and controlling the AV. In all cases the GPS accuracy was too low (~4m) for meaningful use in precision agriculture. A 5G PopUp network can be deployed which provides much greater bandwidth and allows higher data transfer speeds with reduced latency. This allows video streaming, cloud video processing and decision making events for farming in future work.

Metrics	Field 1		Field 2		Field 3	
	Point 1	Point 2	Point 1	Point 2	Point 1	Point 2
Download Speed (Mb/sec)	0.61	0.64	5.8	12.4	0.86	0.95
Upload Speed (Mb/sec)	1.5	1.1	7.8	7.8	6.3	4.1
GPS Accuracy (m)	4		5		5	

Figure 5 Download and upload speeds in fields 1, 2 and 3 and GPS accuracy

To support data collection in future work, in-field sensors were tested to monitor pressure, humidity and temperature. This helps inform decision making events. Here the bandwidth is less critical and these data were sent directly to the cloud via a sim connected Raspberry Pi. Future work will address lower power devices such as LoRa. Figure 6 shows a simple data collection system and data pushed to the cloud. The AV was controlled via a Raspberry Pi and Arduino. These provide inexpensive solutions and simple development opportunities.

Figure 6 In-field sensors and example plots

Added Value

Farmers are often reluctant to grow energy crops because of the length of commitment (e.g. 20 plus years) and uncertain markets without guaranteed uptake. This problem is circumnavigated if additional revenue streams can be achieved from the crop. To this end, potential revenues and savings were assessed from replacing straw for cattle bedding, increasing the energy crop value by washing and torrefaction. Microalgae can be grown utilising volatile emissions from the torrefaction process, reducing Green House Gas emissions by capturing carbon. Figure 7 shows an algal culture being grown for testing and evaluation of the added value from e.g. lipid and protein contents. To make microalgae a viable option, either higher value products need to be produced and/or the amount of harvestable biomass needs to be increased. Figure 8 shows a scaled, 1 m^3 Photobioreactor (PBR) which will be used in future work.

Figure 7 Microalgal culture grown in-house

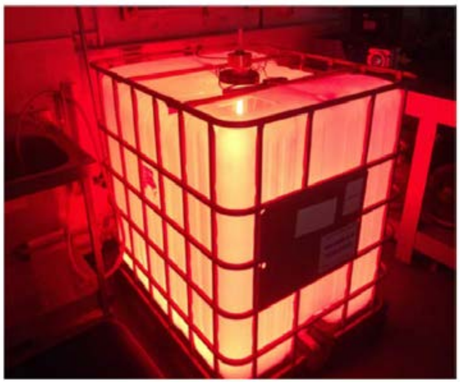

Figure 8 PBR for scaling strategies

The impact of torrefaction on the Miscanthus was investigated, and the product yields for solid, liquid and gases were investigated. Figure 9 shows the torrefaction/pyrolysis reactor, solid product and liquid yield. Clearly there are options to push the outputs towards specific products depending on end user requirements.

Figure 9 Torrefaction experiments showing the reactor, and torrefied and liquid products (left to right)

Life Cycle Analysis

The LCA analysis of the automation of the process assessed the impact of using electric vehicles for farming Miscanthus, and sequestering CO2 from Miscanthus torrefaction.

With a yield of 14 t ha^{-1} $year^{-1}$ of above-ground biomass harvest, ~26 and 2.35 t ha^{-1} $year^{-1}$ are sequestered above and below ground respectively. Energy extraction from the harvested biomass is considered carbon neutral without capturing these emissions. The 2.35 tCO2/ha value includes 0.7 t/ha for on farm activities. In the current case, with the development and implementation of the Intelligent Miscanthus Farming systems, the inputs into farming Miscanthus become zero, reducing the GHG emissions and environmental impact from this approach. By coupling these concepts with added revenue options from microalgal production, farmers can approach carbon neutral Miscanthus farming, this becomes favourable as bioenergy carbon capture sequestration (BECCS) becomes either a preferred strategy or at least a viable option for energy production and carbon uptake, with the carbon balance becoming negative. It should be noted that the development of carbon trading could allow offsetting of other on-farm activities based on the carbon reduction from these approaches. It is also unclear at this stage where carbon negative values would reside.

Future Work

Future work will address the growth of Miscanthus varieties that have been demonstrated to grow in conditions similar to those at Cochno Farm. This will be done using conventional technology while the technology is developed, which will then be tested, developed and deployed.

References

1. John Clifton-Brown *et al* (and Terravesta staff) (2016) Progress in upscaling *Miscanthus* biomass production for the European bio-economy with seed-based hybrids, GCB-Bioenergy, 9, 6-17. https://doi.org/10.1111/gcbb.12357
2. John Clifton-Brown *et al* (and Terravesta staff) (2019) Breeding Strategies to Improve Miscanthus as a Sustainable Source of Biomass for Bioenergy and Biorenewable Products, Agronomy, 9, 673-690 (doi:10.3390/agronomy9110673)
3. Evidence review: Perennial energy crops and their potential in Scotland, Gareth Martin, Leo Ingvorsen, Jessie Willcocks, Jeremy Wiltshire, Judith Bates, Becky Jenkins, Tom Priestley, Helen McKay (Forest Research) and Steve Croxton (Uniper), Ricardo Energy and Environment, June 2020. https://www.climatexchange.org.uk/media/4494/land-use-impacts-of-perennial-energy-crops-in-scotland-december-2020.pdf (last accessed 5/5/21).