RURAL ECONOMY AND CONNECTIVITY COMMITTEE

SUBMISSION FROM THE JAMES HUTTON INSTITUTE

THE DRAFT CLIMATE CHANGE PLAN (RPP3)

The James Hutton Institute (www.hutton.ac.uk) welcomes the opportunity to comment on the Scottish Government's Draft Climate Change Plan: The draft Third Report on Policies and Proposals 2017-2032. Our submission draws on research funded by the Scottish Government Strategic Research Programme (2011-16) and co-funded research by the European Union. In this submission we focus on the topics of agriculture and agro-forestry, for the Scottish Parliament Rural Economy and Connectivity Committee and its consideration of the draft plan.

Submissions are being made by the Scottish Government Centre for Knowledge Exchange and Impact, and the Moredun Research Institute on related topics. The Institute has also made a submission to the Environment, Climate Change and Land Reform Committee, on topics of behavioural change, waste and a circular economy, and peatlands.

Agriculture

(i) **Policy Outcome 1:** Farmers, crofters, land managers and other primary food producers are aware of the benefits and practicalities of cost-effective climate mitigation measures.

Comment regarding policies which contribute to Policy Outcome 1

Increasingly, information and advice on climate change mitigation measures for land managers can be delivered through smartphone-based decision support tools. Tools such as SIFSS (Soil Information for Scottish Soils; https://itunes.apple.com/gb/app/sifss/id581872368?mt=8) and SOCiT (Soil Organic Carbon information; https://itunes.apple.com/gb/app/socit/id631266307?mt=8) developed by the Hutton (SOCiT was also supported by QMS) can contribute to delivery of this policy through use of new technology and media. These Apps provide site-specific soil characterization, linking the Scottish Soils Database, national scale mapping (http://soils.environment.gov.scot/), user location and soil profile image analysis, enabling the identification of management options that increase resilience against climate change. Underpinning research is reported in Aitkenhead et al., (2016). Ongoing work at the James Hutton Institute will improve soil characterisation and link existing soil properties to recommended management options. The Institute will provide further support and updates, funded through the supported by Scottish Government Underpinning Capacity budget.

(ii) **Policy Outcome 2**: Emissions from nitrogen fertiliser will have fallen through a combination of improved understanding, reduced application and better soil.

Comments regarding policy which contribute to Policy Outcome 2

To develop a science-based target for reducing emissions from nitrogen fertiliser

Development of a science-based target for reducing emissions from nitrogen fertiliser can be informed by the modelling and in-field detection of impacts of liming on soil processes, functions and services which includes the effects of liming on nitrogen emissions and runoff. The findings of baseline data for modelling show a wide variation in soil acidity and nutrient content, and are expected to help target fertiliser inputs and develop best practice on reducing runoff (Aitkenhead et al. (2017). The relevant research is a collaboration between the Institute, working with industry, and through the Scottish Government Strategic Research Programme (2016-21), and information disseminated through Rural Environment Science and Analytical Services Division (RESAS).

Soil Testing

The James Hutton Institute has been working with colleagues in Scottish Government RPID to inform decisions on the types of factors to consider when designing a scheme for soil testing. Analysis has considered the types of agricultural activity, area, number of fields and their distribution across Scotland. The findings will provide some of the scientific evidence to support a well targeted scheme. As custodian of Scotland's National Soil Archive (www.hutton.ac.uk/about/facilities/national-soils-archive) and Soil Database (supported by the Scottish Government Underpinning Capacity funding), the Institute can contribute expertise on how the samples collected in a programme could be archived and used as a basis for further analyses. This could include, for example, the impact of changing nutrient status on the ability of soil to provide a range of functions including soil health, its ability to store carbon to mitigate GHG emissions, and water quality. This has the potential to provide insights of value to individual farmers and land managers on the sustainability of their soil management practices and make a major contribution to delivery of Scotland's Soil Monitoring Action Plan to underpin environmental and agricultural policy making.

Proposals which contribute to Policy Outcome 2

Minimum leguminous crops in rotation

Legume crops and forages are likely to fix as much atmospheric N as is presently given each year to spring cereals in the form of mineral fertiliser. Potentially, therefore they can bring about major reductions in fertiliser N inputs to agriculture (more so than potential increases in varietal N use efficiency in cereals). Co-benefits are realised through improving soil structure and residual fertility. Crops such as peas and beans tend to allow a greater diversity of non-aggressive, broadleaf wild plants to grow within them and some (but not all) legumes directly support pollinators. The legume crop itself and its associated flora boost the farmland food web, notably those invertebrates that benefit farming by reducing pests.

The main challenge facing the greater adoption of legumes is the shortage of high value markets, and competition for processing capacity. For example, there is little such capacity in Scotland for supporting aquaculture unless access is increased to that for well-developed fermentation based industries. While mineral N replaced legumes in arable crops during 20^{th} century intensification, imported legume material, in the form of GM soya protein, more recently replaced their function in much grassland and stock rearing.

However, research is being undertaken at the James Hutton Institute to develop crop varieties, processing methods and end uses that would facilitate transitions to an expanded use of legume protein in the food chain. In addition, our current approaches to whole-system design are being tested at the James Hutton Institute, at the Centre for Sustainable Cropping (supported by the Scottish Government Underpinning Capacity funding). The aim is to identify those combinations of legumes, forages and other crops that would satisfy a range of ecosystem services (including farm profit) in the field, rotation and landscape.

Early work on this topic, from assessments of crop rotations throughout Europe in a co-funded EU project (www.hutton.ac.uk/research-partners/legume-futures), established that optimal legume inclusion, that is which gave highest biomass and N outputs and levels of biological nitrogen fixation, and lowest additions of inorganic nitrogen fertiliser, was achieved at 50% inclusion (i.e. legumes in half of the rotation-years). On average, this level of inclusion was achieved with an equal balance of forage and grain legume types, and in many cases the presence of the legume did not displace a non-legume crop, as the two crop types were intercropped. The non-legume nitrogen provision was supported by the legume crop. Recent studies have shown such intercropping of legume (pea) supported cereal (barley) yields 20% more that monocrops, which is not uncommon and occurs despite the lack of inorganic nitrogen (Iannetta et al., 2016).

Currently, the Scottish arable area (excluding grass), is sown with barley c. 60% of the time. Of this barley, half is destined for animal feed markets, the rest for malting. The Institute's work on intercropping showed that barley-pea combinations yield 1.2 times more per unit area – this yield comprising 80% barley and 40% pea. The barley qualities appear good as the nitrogen range of the intercropped grains seems suitable for malting - and tests of this are underway. The legume grains are also being tested for brewing and distilling – with high protein co-products for processing as novel feed (and even food) ingredients.

There are also positive cost benefits to the soil qualities, encouragement of natural chemical cycling and associated soil microbial diversity and fertiliser offset for subsequent crops in the rotation. Similarly, there are benefits of health and wellbeing of greater levels of pulse consumption by animals and the general public. The benefits shown, financial and CO_2e are therefore an underestimate of what might be achieved.

Plant varieties with improved Nitrogen-use Efficiency

Nitrogen, the element of highest concentration in plant tissue, is tightly coupled to total plant biomass. High yields mean high N inputs since the protein-N that plants make is essential for the end products, whether bread, brewing, malting or animal feed. N use efficiency depends on both crop characteristics and agronomy.

In Scotland, N use efficiency was lowest at the end of the main phase of crop intensification in the late 1980s and early 1990s. It subsequently increased, as a result of more efficient supply of N to crops due to, e.g. the EU Nitrates Directive and Set-Aside, and also to the deployment of crop varieties that allocated more of their dry biomass and N to grain. However, in the most N-efficient arable agriculture in Scotland, there is now limited scope for reducing the N inputs of crops, especially by genetic improvement, since (as indicated earlier) much of what goes on the field is taken off in the grain or grass.

The main opportunities for improving N use efficiency in the system are to ensure the flush of N from crops to the soil from dead plant material at harvest is not lost to the wider environment but taken up by other vegetation such as under-sowings, a 'catch' crop, field margins or beneficial 'weeds'. Legume-cereal mixed crops could reduce N input to the cereal but, currently, such systems are not so well understood as to ensure that no loss of yield occurs in the cereal if that is the primary output. That is, management options using more strategic deployment of legumes, linked to the development of innovative new and efficient fertilisers (for non-organic production units), are capable of delivering significant benefits in the near term.

This success is even more remarkable considering that crop types developed for intensive production were used. The nitrogen use efficiency of legume and non-legume crop types needs to be improved urgently for intercropped (legume-supported) cropping systems. Currently, the James Hutton Institute is pre-breeding major crop types for that purpose, so delivering to the proposal in support of the Policy Outcome. In addition, accurate quantitative estimates of N usage, stores and fluxes are now being made for the main crops with a view to designing the most N efficient cropping systems.

Collectively, these developments will assist the Scottish Government in its aims of delivering on Policy Outcome 2.

Policy Outcome 5: The carbon content of soil and agricultural land will have improved through carbon sequestration and expanded woodland/forestry and hedgerows

Proposals which contribute to Policy Outcome 5

Payment for carbon sequestration will be guided by information on soil carbon content and other soil characteristics that help or hinder carbon sequestration (e.g. soil texture, topography) for site-specific guidance to farmers. Modelling and mapping work within the Scottish Government Strategic Research Programme (2011-16) provided spatial estimates of Scottish soil carbon distribution (e.g. Aitkenhead & Coull, 2016; Poggio & Gimona, 2014; Baggaley et al., 2016) and information about differences between current carbon stocks and potential maximum carbon stocks (Lilly & Baggaley, 2013).

Other work, funded under the Scottish Government's ClimateXChange (CXC) programme, has determined the changes in carbon stocks through time, both above and below ground and for the whole of Scotland, following a change in land cover from its current use to woodland. Depending on the soil and rotation length, planting trees does not always result in a net sequestration of CO_2, as losses from the disturbance at planting can outweigh the gains through later growth. Collectively, the findings of this research provide information on relationships between soil carbon sequestration and climate, topography and management. This and ongoing work will allow determination of potential carbon sequestration in soils across Scotland.

Agro-forestry

It is puzzling that agroforestry did not receive more mention in the draft Climate Change Plan, particularly as it is referred to in the UK Committee on Climate Change progress report on Reducing Emissions in Scotland 2016 (Committee on Climate Change, 2016). Agroforestry is where trees and crops are grown together on the same land, similar to the intercropping mentioned above. It has the potential to sequester significant quantities of CO_2 from the atmosphere as well as supporting co-benefits. Much research has shown that there is a synergistic effect whereby both species benefit from the presence of the other so that the combined yield is greater than when they are grown separately. The main reason why agroforestry has not been adopted more is that the grant schemes favour either woodlands or arable crops, but not where the two are grown together. With recent changes in the SRDP, this situation may change, but there is still a considerable need for further research to determine the best combination of tree species and crop varieties, as well as planting arrangements, for Scottish conditions. The long-term agroforestry trials at the James Hutton Institute can be used to provide some of this information.

References

Aitkenhead, M.J., Coull, M.C., 2016. Mapping soil carbon stocks across Scotland using a neural network model. *Geoderma* 262, 187-198.

Aitkenhead, M.J., Coull, M.C., Gwatkin, R., Donnelly, D., 2016. Automated soil physical parameter assessment using smartphone and digital camera imagery. *Journal of Imaging* 2(4), 35; DOI 10.3390/jimaging2040035.

Aitkenhead, M.J., Gaskin, G.J., Lafouge, N., Hawes, C., 2017. PHYLIS: A Low-Cost Portable Visible Range Spectrometer for Soil and Plants. *Sensors* 2017, 17(1), 99.

Baggaley, N., Poggio, L., Gimona, A., Lilly, A. 2016. Comparison of traditional and geostatistical methods to estimate and map the carbon content of Scottish soils. In Digital Soil Mapping Across Paradigms, Scales and Boundaries (Eds Zhang, G.-L., Brus, D., Liu, F., Song, X.-D., Lagacherie, P. Digital Soil Mapping Conference 2014 Nanjing, China. Springer.

Committee on Climate Change, 2016. Reducing Emissions in Scotland: 2016 Progress Report, September 2016. pp.95.

Iannetta et al. 2016. A Comparative Nitrogen Balance and Productivity Analysis of Legume and Non-legume Supported Cropping Systems: The Potential Role of Biological Nitrogen Fixation, *Frontiers in Plant Science*, doi.org/10.3389/fpls.2016.01700.

Lilly, A., Baggaley, N.J., 2013. The potential for Scottish cultivated top soils to lose or gain soil organic carbon. *Soil Use and Management 29, 39-47.*

Poggio, L., Gimona, A., 2014. National scale 3D modelling of soil organic carbon stocks with uncertainty propagation – an example from Scotland. *Geoderma* 232, 284-299.

Submitted by the James Hutton Institute.

Compiled by D.R. Miller, M.J. Aitkenhead, H.I.J. Black, M.C. Coull, P.P.M. Iannetta, A. Lilly, K.B. Matthews, R.B. Matthews and G.R. Squire.