Investigating the relationships between pasture species, soil characteristics and management inputs on the North Wyke Farm Platform at Rothamsted Research, North Wyke, Devon, UK

29 May – 19 August 2018

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I give my consent to the report being posted on the Co-operative Research Programme's (Biological Resource Management for Sustainable Agricultural Systems Theme 1) website

Summary

New Zealand and the UK rely on resilient pastoral landscapes for economic prosperity. These landscapes are threatened by extreme climatic events and issues associated with agricultural intensification which can lead to degradation of soil and loss of water quality. Steep hill country is especially prone to soil degradation, and comprises 40% of agricultural land in New Zealand. Research is required to better understand interactions between production and the environment to develop practices and policy that enhance productivity while protecting the environment.

This collaborative and multi-disciplinary OECD-funded project brought together the applicant Dr Tozer, from AgResearch (New Zealand) and scientists from Rothamsted Research (UK), with capability in ecology, agronomy, statistics and farm systems. We have used the North Wyke Farm Platform (NWFP), a large farm-scale experiment comparing three approaches for improving pasture production, to examine relationships between management inputs, and pasture and soil characteristics that influence production and the environment.

The fellowship provided a unique opportunity to investigate relationships between botanical composition, soil characteristics and pasture management within the NWFP, by accessing the existing long-term dataset and collecting additional vegetation data through field mapping during the fellowship. Lessons from the fellowship will provide a strong evidence-base to develop sustainable pasture management practices and inform future policy in New Zealand, the UK and internationally.

Introduction

New Zealand and the UK rely on resilient pastoral landscapes for economic prosperity. Steep hill country is particularly important for cattle and sheep farming in New Zealand and comprises 40% of its agricultural land [1]. Over half of New Zealand's cattle and sheep are farmed on these hill country grasslands, which are too steep to cultivate and extremely challenging to farm. Despite the challenges, livestock production from steep hill country grasslands adds more than NZ$4 billion per annum of export revenue to the New Zealand economy. Grasslands are similarly critical for agricultural production in the UK. They comprise 76% of the total UK agricultural land area, with sheep and cattle production from this land providing a net worth to the UK economy of around £8 billion per annum [2].

With the intensification of agriculture, the natural capital of grasslands is under threat. This includes increasing vulnerability of hill country to environmental shocks such as climate change [p 4, [3]]. Under predicted climate change scenarios, extreme weather events, such as droughts and storms, will become more frequent and widespread [4]. This has implications for the persistence of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) which are shallow-rooted and vulnerable to drought, despite being the most frequently sown species in productive temperate pastures in the UK and New Zealand [5, 6] Extreme weather events are likely to increase soil erosion, which is the most critical environmental issue affecting land in New Zealand [4]. Approximately 1.14 million hectares of hill country are classified as erosion-prone, which is estimated to cost NZ$100-150 million per annum [7].

The New Zealand government's target of increased agricultural production and doubling of export values by 2025, as detailed by the New Zealand Ministry of Primary Industries [8]**,** has the potential to put pressure on New Zealand's pastoral landscapes. Research is required to better understand these issues and to meet the productivity targets.

North Wyke Farm Platform

The Rothamsted Research North Wyke Farm Platform (NWFP), Devon, UK, is a 63 hectare farm-scale experiment designed to quantify production and ecosystem responses to different sheep and beef management practices and develop sustainable pasture management solutions. The three management systems examined (across three 21 ha NWFP farmlets) are based on pasture improvement and livestock production through use of:

- Addition of mineral fertilisers (sustainable intensification of permanent grassland) ('green' Farmlet);
- Addition of legumes ('blue' farmlet); and
- Reseeding pastures with deep-rooted Festulolium and high nutritive value perennial ryegrass cultivars; (i.e. planned reseeding with novel varieties and species mixtures) ('red' farmlet).

Since 2011, 198 parameters have been monitored every 15 minutes using 108 instruments (water quantity and quality, soil moisture, meteorological data). These are supplemented by botanical, soil nutrient and other field surveys which provide valuable spatial information based on a 25 m or 50 m GIS sampling grid (with the sampling grid resolution depending on the data being collected). Data sets are available from the NWFP data portal (https://nwfp.rothamsted.ac.uk/).

The resources, infrastructure and unique datasets of the NWFP allowed the recipient in collaboration with Rothamsted Research scientists to investigate relationships between the botanical composition, soil characteristics and management factors on the NWFP.

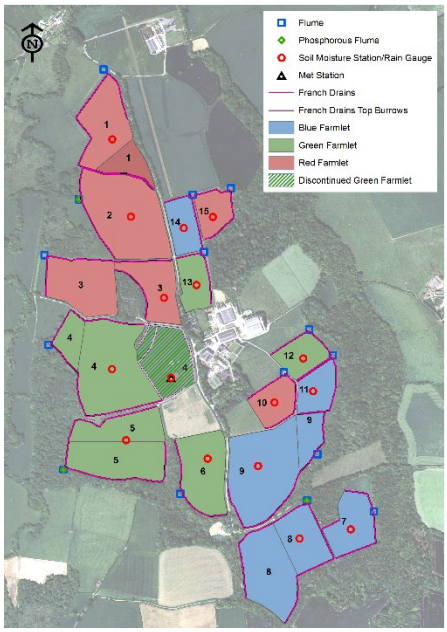

Figure 1. Diagram of the North Wyke Farm Platform showing the treatment layout. Fields in the red farmlet were reseeded with *Festuloliums* or ryegrass and those in the blue farmlet with ryegrass and white clover while fields in the green farmlet were permanent pastures (>20 yr old).

The objectives of this research project were to harness the complementary skill-sets of AgResearch and Rothamsted Research scientists with capability in ecology, agronomy, statistics and farm systems, and the infrastructure and resources of the (NWFP) to investigate:

(1) At paddock scale, the impact of farm management inputs on botanical diversity and persistence of sown species in the three pasture improvement treatments.

(2) How the distribution of plant species and their nutritional status is associated with soil characteristics.

(3) Any relationships found and review overall findings to inform existing policy, research, teaching, extension and future collaboration opportunities.

Why is the research important?

To date, little research has been conducted on the NWFP's botanical data sets (baseline & post-baseline) and this project has addressed this gap. Analyses are in progress to determine how the botanical composition has changed over time and how it is related to farm management inputs and soil characteristics.

This research provides knowledge to address both the environmental concerns and productivity targets. Lessons will be used to inform the development of sustainable management practices and policies to enhance the productivity of the pastoral sector while maintaining and improving the land and water quality in New Zealand [9] and the UK. Sustainable management practices are sought by Regional Councils and industry bodies, given the increasing focus on protecting New Zealand's soils and waterways. Likewise, the project will provide research outputs that contribute to developing sustainable management guidelines for UK grasslands as strategically prioritised in Biotechnology and Biological Sciences Research Council's Agriculture and Food Security Strategic Framework (2016-2021).

Major achievements (up to three)

Achievement 1: A botanical field survey was undertaken. Ground cover of all species present in each of 0.50 m^2 quadrats in 395 sampling locations was categorised using the Domin Scale [10]. Pasture was also harvested to ground level in 120 of the 395 quadrats, the harvested vegetation subsampled and dissected in the lab into individual species and their dry weights obtained. This enabled an estimate of the percentages in total dry matter for each species to be estimated. The work was done by the OECD fellowship recipient in collaboration with other Rothamsted Research staff.

Field survey data collected during this fellowship were combined with data on soil characteristics and farm management variables (collected by Rothamsted Research staff). Meetings were held with Rothamsted Research scientists to determine the best approach for data analyses of the combined datasets. Data analyses are in progress (aligned to aim 1 and aim 2) to test the hypothesis that *Management is more important than environmental factors in determining species composition*. A Principal Coordinates (of) Neighbour Matrices (PCNM) approach will be used to undertake multi-scale analyses of the spatial and temporal datasets.

A preliminary multivariate analyses (Figure 2) of the 2018 botanical composition data by Dr Jonathan Storkey from Rothamsted Research show that pasture age and pasture management explained 57% of the variance in botanical composition. Reseeding with ryegrass or *Festuloliums* (Red farmlet) was most strongly associated with the ingress of the unsown perennial grass *Alopecurus geniculatus* (meadow foxtail), while reseeding with ryegrass and white clover (Blue farmlet) was strongly associated with the

sown white clover and ingress of the unsown forb *Ranunculus repens* (creeping buttercup). Increasing pasture age and old permanent pastures (i.e. the Green farmlet) were also strongly and positively associated with the ingress of unsown *Agrostis stolonifera* (creeping bent grass). The presence of these unsown species and negative association in all farmlets with ryegrass demonstrate how ryegrass was not strongly persisting where it had been sown.

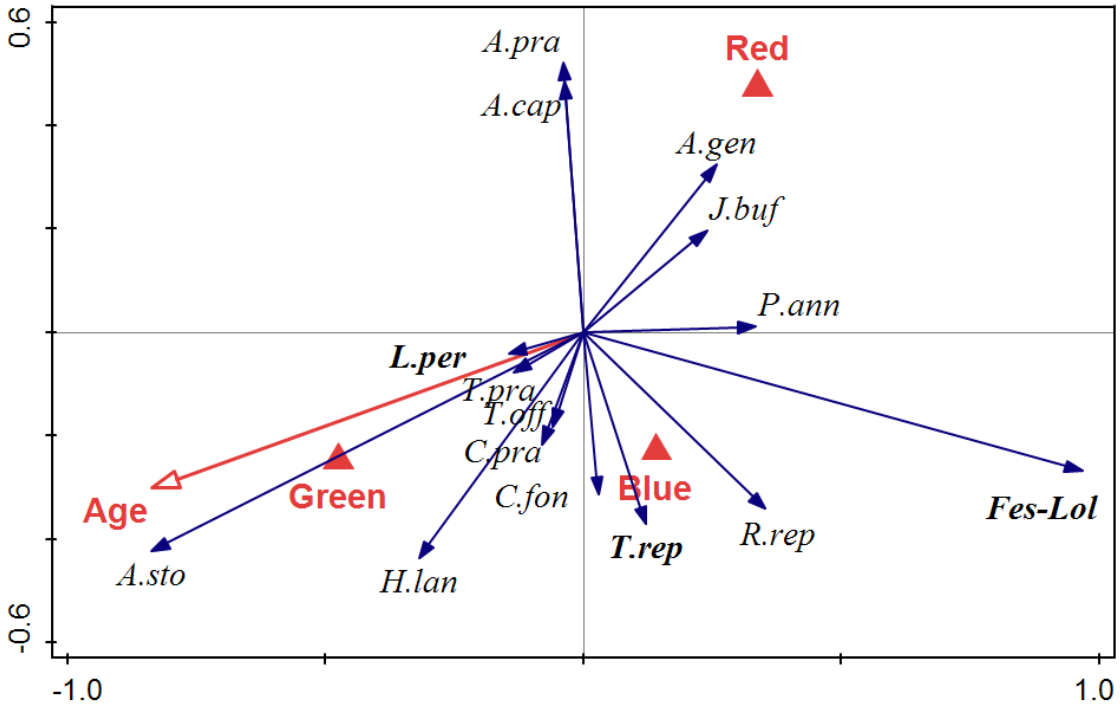

Figure 2. Redundancy Analysis (RDA) using 2018 proportional biomass data. Age of pasture input as continuous variable with Green treatment fields assigned an age of 20 years. Species data log transformed and only top 15 best fitting species shown. Combination of age of pasture and management treatment explained 56.6% of the variance in species composition. *A.cap = Agrostis capillaris, A.gen = Alopecurus geniculatus, A.pra = Alopecurus pratensis, A.sto = Agrostis stolonifera, C.fon = Cerastium fontanum, C.pra = Cardamine pratensis, Fes-Lol = Fescue-Lolium, H.lan = Holcus lanatus, J.buf = Juncus bufonius, L.per = Lolium perenne, P.ann = Poa annua, R.rep = Ranunculus repens, T.off = Taraxacum officinale, T.pra = Trifolium pratense, T.rep = Trifolium repens.* Sown species in bold. Fields in the Red farmlet treatment were reseeded with *Festuloliums* or ryegrass and those in the Blue farmlet with ryegrass and white clover while fields in the Green farmlet were permanent pastures (>20 yr old).

There were effects of management on botanical diversity although the total number of species was low (Figure 3). The greatest number of species was associated with ryegrass + clover-based pastures (Blue farmlet, averaging ≈ 3 species per quadrat), an intermediate number with ryegrass-based pastures (Red farmlet, ≈ 2 species), and the lowest number was associated with the old permanent pastures (Green farmlet, ≈ 1.5 species).

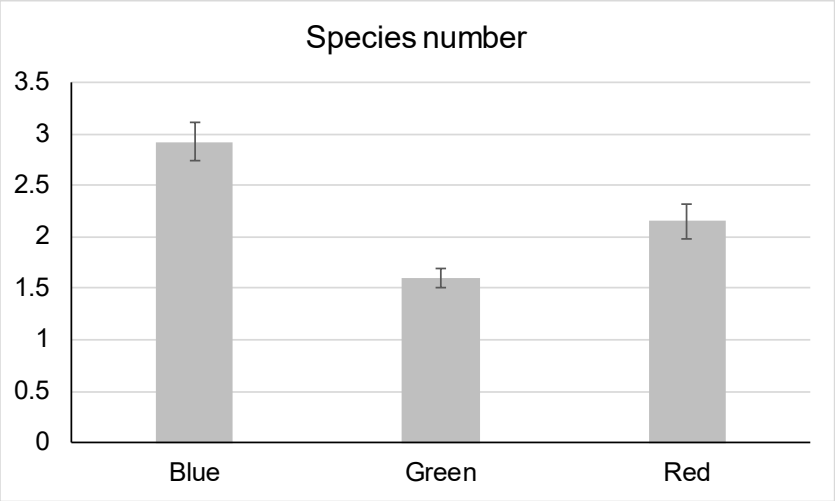

Figure 3. Species diversity (average number of species per quadrat) in the Blue, Green and Red farmlets on the North Wyke Farm Platform, Rothamsted Research. Fields in the Blue farmlet were seeded with ryegrass and white clover, and in the Red farmlet with *Festuloliums* or ryegrass, while those in the Green farmlet were permanent pastures (>20 yr old).

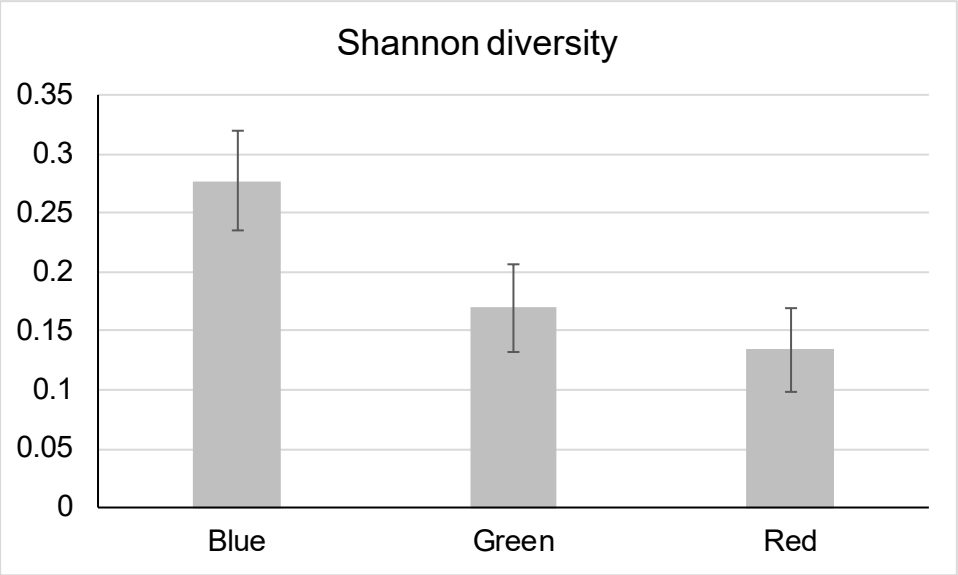

Figure 4. Shannon Diversity Index in the Blue, Green and Red farmlets on the North Wyke Farm Platform. Fields in the Blue farmlet were seeded with ryegrass and white clover, and in the Red farmlet with *Festuloliums* or ryegrass, while those in the Green farmlet were permanent pastures (>20 yr old).

Shannon's Diversity Index (which takes into account both the number of species present and their relative abundance / how evenly the species are distributed) was greater in the ryegrass and clover-based pastures than in the ryegrass only-based pastures and permanent pastures ($P<0.05$, Figure 4). Overall, the species diversity in all pasture types was low, which is typical of intensively managed grasslands. Further analyses are required to relate management inputs and soil characteristics to the botanical composition.

Achievement 2: On-going analyses of these extensive spatial and temporal botanical and soil datasets will provide opportunities for the inter-disciplinary team to grow in their knowledge of how the three systems and associated soil factors are related to the botanical composition. This information will enable a joint authorship publication to be prepared for submission to an international journal. Results on the invasibility of the swards and associated soil characteristics will be used to develop more sustainable farm management practices which are sought by Regional Councils and industry bodies, given the increasing focus on protecting New Zealand's soils and waterways. Likewise, the project provides research outputs for sustainable practises in the UK as strategically prioritised in Biotechnology and Biological Sciences Research Council's *Agriculture and Food Security Strategic Framework* (2016-2021).

Achievement 3: As a result of this fellowship, meetings have been held and funding sources identified to which we will apply for financial support to undertake collaborative research on Future Grazing Systems: Developing 21st Century Pastures (aligned to aim 3).

Follow-up:

Is a publication envisaged? Will this be in a journal or a publication? When will it appear? *A joint manuscript is being prepared for submission in 2019 to an international journal (e.g. Journal of Applied Ecology) which investigates the relationships between pasture species, soil characteristics and environmental variables on the North Wyke Farm Platform.*

Is your fellowship likely to be a start for collaboration between your home institution and your host? *As a result of this fellowship, meetings have been held and funding sources identified to which we will apply for financial support to undertake collaborative research on Future Grazing Systems: Developing 21st Century Pastures*

Is your research likely to result in protected intellectual property, novel products or processes? *The research will not result in protected intellectual property or novel products or processes.*

How might the results of your research project be important for helping develop regional, national or international agro-food, fisheries or forestry policies and, or practices, or be beneficial for society? *Please express this in terms of environmental/food security/food safety/economic/health (human and livestock and plant) benefits, etc.*

The envisaged outcomes of this project, of developing sustainable pasture management strategies that enhance production while reducing the impact on natural capital, have national and international policy relevance.

- Nationally:
  - *New Zealand:* The proposed research is consistent with National Government directives for AgResearch, a Crown Research Institute, to undertake research on *farm systems for sustainable livestock production* that are more profitable and which have a lower environmental impact [NSSI, p16, 3].
  - Lessons from the fellowship are relevant for New Zealand pastoral industry organisations such as Beef + Lamb New Zealand. Learnings will be communicated with the mid-Northern North Island Beef and Sheep Farmer Council, who have an extensive communication network throughout the upper North Island of New Zealand. This process will assist in disseminating and using the new knowledge to underpin the development of future policy within New Zealand. For example, policy that will deliver to the New Zealand Government's *Business*

Growth Agenda 2017, which aims to improve the productivity of the land while reducing the environmental impacts [p45, 17]).

- Knowledge gained from this project will contribute to developing more sustainable pasture management strategies which can be used by industry bodies such as Beef + Lamb NZ and Regional Councils.
- *United Kingdom:* Within the Biotechnology and Biological Sciences Research Council's Strategic Priorities, this project fits with the strategic economic opportunities and societal challenges in the *Agriculture and Food Security Strategic Framework* (2016-2021).

- *Internationally:* Outcomes are strongly aligned with the UN's Paris agreement on climate change. Specifically, the outcomes are consistent with UN support of *actions to build resilience and decrease vulnerability to the adverse effects of climate change* [Paragraph 135, 18]

How was this research relevant to the objectives of the CRP and the CRP research theme?

The short and long-term goals of this research fully align with OECD's Theme 1 objective of managing natural capital for the future through sustainable resource management. The fellowship is contributing to developing new knowledge by investigating temporal and spatial relationships between botanical composition, management inputs and soil characteristics. This knowledge is critical for developing evidence-based and innovative sustainable pasture management practices for Regional Council policy in the UK and NZ that enhance productivity while protecting our soils and water.

Satisfaction

Did your fellowship conform to your expectations? *The fellowship conformed to my expectations. I was able to undertake the planned work and held meetings with scientists to plan future collaborative research.*

Will the OECD fellowship increase directly or indirectly your career opportunities? Please specify. *The fellowship will help me by improving my chances of obtaining further research funding through opportunities for further international collaboration.*

Have you encountered any practical problems. *I encountered no practical problems.*

Please suggest any improvements in the fellowship Programme. *I cannot think of any improvements; I was extremely satisfied with the fellowship.*

Advertising the Cooperative Research Programme

How did you learn about it? *I learnt of the fellowship from an internal email from my research institute (AgResearch).*

What would you suggest to make it more "visible" *Contacting the Crown Research Institutes in New Zealand to ensure that they are aware of the OECD fellowships and asking them to circulate emails to their research staff.*

Any issues you would like to record?

Thank-you for providing the funding to visit North Wyke Research. The visit was extremely productive and has opened up opportunities for further collaboration. Please pass on my thanks to the committee members at their next meeting.

Many thanks also to North Wyke staff (in particular Paul Harris and Deb Beaumont) for all they did to make the visit so productive and enjoyable.

Regards,

Katherine Tozer

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