Biodiversity benefits to agriculture in complex tropical landscapes (Ref IAP2-18-119)

Newcastle University, SNES
In partnership with University of Durham, Reforest Africa, and Tanzanian agribusiness

Supervisory Team
- Dr Marion Pfeifer, Newcastle University
- Prof Stephen Willis, University of Durham
- Dr Rachel Gaulton, Newcastle University
- Dr Andrew Marshall, Reforest Africa (Tanzania) and USC (Australia)

Key Words
1. Biodiversity benefits to and from agriculture
2. Crop benefits: yield, damage, productivity
3. Agroforestry
4. Ecosystem services: pollination, pests and pest control

Overview

Agricultural expansion to meet demands for food and livelihood securities in tropical landscapes can cause biodiversity loss as natural habitats are cleared to make space for farmland\(^1\). This conversion is accompanied by the fragmentation of natural habitats into increasingly smaller and isolated habitat patches\(^2\). The land separating habitat patches, i.e. the matrix, has the potential to support wildlife by facilitating movement or providing resources\(^3\). Wildlife-friendly farming can act with habitat ‘corridors’ and ‘stepping stones’ to produce heterogeneous landscape mosaics\(^4\) rich in biodiversity. This biodiversity can provide essential services to farmland, which has been suggested to contribute to crop health and yields: (1) agroforestry trees intercept rainfall and provide shade thereby reducing water loss from soils; dead leaves and branches provide soil cover and nutrient inputs and protect soil macro-fauna from thermal stress; (2) (semi)-natural habitats provide resources to pollinators and natural enemies of pests\(^5-7\).

Landscape restoration programs are implemented in many tropical landscapes to restore health and functioning especially of forest ecosystems. Guidelines informing restoration exercises (what species, where, over what minimum area) are rare and seldom informed by scientific data. In this project, the student would produce evidence to inform landscape restoration that can meet the objective of supporting sustainable farming (e.g. biodiversity benefits to soil health, pollination), whilst fulfilling other services (e.g. trees for carbon sequestration, conservation of threatened species in remaining natural habitat patches) and mitigating disservices (support for pest species, loss of land for crop production).

This project aims to identify the net benefits of biodiversity provided by natural and semi-natural habitats (from single agroforestry trees and small wildflower patches to tree lines and large patches of natural forests) to farms. In particular, the PhD will implement these analyses for a well-studied target landscape, which has become a central site for forest restoration programs in Tanzania and is the subject of the FORCE experiment, on which Dr Pfeifer is a Co-I (http://force-experiment.com): the landscape encompasses the border between the fragile forests of the Udzungwa Mountains and the productive croplands of the Kilombero in Tanzania. We build on relationships we have established in the study landscape over decades working with local partners, i.e. Sokoine University of Agriculture and Reforest Africa. The Kilombero Valley is a water catchment area and an important ecological bank hosting wetlands, fertile soils, and wildlife. It is also part of Tanzania agricultural growth corridor producing substantial amounts of rice, maize, sugarcane, cacao and other cash and food crops.
The project will identify best practices for landscape restoration in the target landscape that are aimed at maximising the net contribution of biodiversity services from (semi-)natural habitats to cropland in tropical forest-agricultural landscapes. The project will use the derived knowledge to generate a general framework guiding landscape restoration for that objective in similar landscapes.

The PhD will address five key goals:
1. Measure and map key metrics describing quality of crop and (semi-)natural habitats in the study landscape:
   - Measure and map vegetation canopy structure
   - Measure and map vegetation thermal stress, biomass/yield and greenness
2. Measure and map abundance of key taxa in the landscape and habitat dependencies:
   - birds
   - invertebrates: butterflies, bees, beetles
   - food plants
3. Quantify causal spatial relationships between the quality and distribution of (semi-)natural habitats in the landscape and biodiversity benefits (and disservices) to crops:
   - Quantify relationship with crop yield
   - Quantify relationship with crop damage
   - Quantify relationship with abundance/distribution of pollinators, pests and pest controls
4. Simulate loss or restoration of (semi-natural) habitats in restoration scenarios and predict impacts on biodiversity benefits to crops
5. Develop framework for practical landscape restoration in the study landscape aimed at maximising the net contribution of biodiversity services from (semi-)natural habitats to cropland

All chapters will be written as paper submissions. Spatial statistics used include standard modelling approaches and using in-house developed modelling approaches to analyse biodiversity change in response to habitat quality. Network robustness modelling in response to loss or gain in natural habitats will follow Evans et al. 2015 working with Dr Evans (SITES, Newcastle University). The student will interact with Reefstore Africa, academic supervisors, local agribusiness, rural farmers and Tanzanian government authorities Tanzania Forest Service and TANAPA to share project findings.

**Timeline**

Months 1-10: The student will implement a review of the scientific and grey literature to compile the best available data on biodiversity-regulated services and disservices provided from (semi-) natural habitats in forest-agricultural landscapes to farms in the tropics (thesis chapter 1). The student will design the sampling protocols and apply for field permits.

Months 11-17: Fieldwork involving collection of vegetation structure and quality data from crop and non-crop habitats (objective 1) and species surveys (objective 2) will be carried out on two small-holder farms and one industrial farm in central Tanzania, in the Udzungwa mountains biodiversity hotspot and neighbouring Kilombero Valley. The landscape is part of the FORCE project, currently measured for forest structure, health and resilience in a network of 100 permanent forest monitoring plots (PI Dr Marshall, University of Sunshine Coast, Australia; Co-I Dr Pfeifer Newcastle University). The student will be able to benefit from these measurements for his/her studies. The student will interact with local assistants employed for the FORCE fieldwork and with the PhD student implementing the forest resilience experiments.

Months 18-30: Data will be processed and analysed: vegetation data will be collected and processed following (objective 1). They will be linked to remote sensing data to develop maps for the landscape following (objectives 1 – 3; thesis chapter 2). Species data will be processed to link species to habitats (objectives 2 & 3; thesis chapter 3). Biodiversity services (and disservices) provided from the (semi-) natural habitats to the croplands in the landscape will be summarised and quantified and analysed for trade-offs to test for net benefits of biodiversity to crop. This will be combined with modelling impacts of habitat loss and restoration in the target landscape (objective 4) (thesis chapter 4).
Months 31-42: Thesis chapter 5 will focus on the development of the framework aimed at improving agroforestry practices on the ground. The student will present findings to local farmers, development NGOs and at one major international and one major national ecological conference.

Training & Skills

The student will receive training in key skills relevant for conservation and management in changing human-modified tropical landscapes: (i) standard habitat and biodiversity surveys, (2) remote sensing data and GIS to analyse and map ecological data in dynamic landscapes, (3) ecological network construction and analyses, and (4) spatial modelling to predict changes in ecological functions under changes in land use and management.

Novelty: The work is highly interdisciplinary allowing the student to tap into and benefit from research, practice and teaching of the relevant research groups at Newcastle University (Modelling, Evidence and Policy RG at the School of Natural and Environmental Sciences: conservation science, ecological resilience, remote sensing using satellite data; Geomatics RG in the School of Engineering: remote sensing from the ground and using UAVs), the University of Durham (biodiversity modelling), the University of Sunshine Coast Australia (restoration of forests in degraded tropical landscapes) and the project partner Reforest Africa in Tanzania (land management on the ground). Further support will be provided through Dr Platts (University of York: climate change & human population growth) and Dr Darren Evans (Newcastle University: network ecology group leader).

References & Further Reading


Further Information

This project is in competition with others for funding. Success will depend on the quality of applications received, relative to those for competing projects. For further information, or if you are interested in applying, contact

Dr Pfeifer at marion.pfeifer@newcastle.ac.uk (cc Dr Gaulton at rachel.gaulton@ncl.ac.uk)

In your email include:
1) a two-page covering letter detailing your reasons for applying & why you have selected this project,
2) your CV with contact information for ≥ two references,
3) Full transcripts of previous qualifications obtained to date.

Only the best applicants will be asked to submit an application to the University. Students are encouraged to contact Dr Pfeifer in advance for consideration.