FELLOWSHIP SUMMARY REPORT

Author and Fellowship Grant Recipient: Matt Smith, Joint Nature Conservation Committee (JNCC), UK

Subject Title: A Landscape Approach to Maintaining Chile's Natural Capital through Sustainable Viticulture

Theme One: Managing Natural Capital for the Future

Host Institution: University of Austral, Chile

Host Collaborator: Dra. Olga Barbosa

Dates of Fellowship: 5 September to 3 December 2022 (postponed from 2020)

Contact: maescorporate[at]gmail.com

Project objectives and importance

The objective of the research conducted under this fellowship is to secure resource to further enhance and validate the approaches already developed in the pilot phase that was completed in 2019 < https://jncc.gov.uk/our-work/chile-viticulture-project-introduction/>. The project sought to deliver locally relevant models that can be used to inform sustainable natural capital management by private industry partners. The final outputs seek to address the social, economic, environmental and political nexus which the OECD, amongst others, recognises as critical in order to achieve long-term behavioural change required to balance the use and preservation of natural ecosystems and the service they provide society.

The detailed objectives of the fellowship activities are as follows:

A. Enhance land cover map: Additional field data will be gathered to validate the model and develop further land classifications; particularly for classes deemed critical natural capital assets for delivering ecosystem services.

B. Re-training model parameters using local data: Data will be assessed, geocoded, cleansed and modified ready for use in the modelling process.

C. Improving existing nodes of the Bayesian Belief Network: This will include: information on vegetated buffer strip spatial arrangement and composition, cover crop species and their management, the types of fungicide, herbicide, organic and chemical fertiliser and pesticides that are used, including their application methods, and cattle grazing regimes.

D. Developing unpopulated nodes of Bayesian Belief Network: Gather information for ecosystem services related to: natural crop pest management, wild yeasts used for fermentation in biodynamic wines, and 'killer yeasts' that function as biocontrol for crop damaging microorganisms, and management impacts on aesthetic appeal.

E. Design model parameters: Investigate the potential design of new parameters that can be further developed to provide more accurate modelled results.

F. Development of advice products: Advice products enabling stakeholders to better understand the concepts of ecosystem services and natural capital, how these function in relation to strategic landscape management.

Results and Achievements

The fellowship was delayed for over two years due to the global outbreak of the Covid-19 pandemic. Due to this considerable delay, the project lost six key personnel who moved out of the respective organisations, went on maternity leave, or were promoted internally and therefore assigned new work portfolio priorities. This resulted in the access to some of the key skills being disrupted and resulted in JNCC having to upskill inexperienced staff members in the use of the modelling software. In a sense, this CRP Fellowship provided the perfect project for this to take place as it sits outside of the usual Grant in Aid and official advice portfolios, thus providing opportunities within JNCC for new staff to work on international workstreams.

A. Enhance land cover map

It was possible to ground validate the missing landcover classes and collect data points for these within the Colchagua Valley study area, which helped increase the confidence and accuracy of the landcover mapping algorithms. However, the missing land cover classes were shown to be less of an impacting factor on ecosystem service modelling, compared to land use and crop types present in the study area. To address this it was necessary to purchase crop map data for the study area, containing the field boundaries, crop types, rotational frequency, amongst other parameters. This was purchased from the Chilean Centre for Information on Natural Resources (CIREN) <https://www.minagri.gob.cl/institucion/ciren/>. In order for this data to be incorporated into the ecosystem service models, it is necessary to collect physiological parameters on the diverse types of crop present, including: base, optimal and flowering temperature thresholds; leaf area indices; maximum root depths; radiation use efficiency; stomatal conductance; and canopy heights. This information is imperative for accurately ascertaining soil, water, and atmosphere interactions to indicate how different land uses and their associated land cover (including crop types)

affect the natural processes occurring at the landscape level, vis-à-vis their potential impacts on natural ecosystems and their services. Wine grape vines are only a small proportion of the 41 different crops grown in the Colchagua Valley. The aforementioned crop physiology data required for the models are not readily available, with information being scattered across various information sources including scientific literature, industry publications and non-peer reviewed grey literature; published in both English and Spanish. Furthermore, the data are not uniform and contain a range of different measuring units. Data needed to be converted into metric measurements for accurate comparison and for use in the models. Locating, gathering and compiling this information proved to be highly time consuming and the completion of the database of the crop parameters is ongoing. It is possible to run models using general parameter information provided in the general reference database of the SWAT model. However, the application of these parameters was a significant limitation of the first phase, thus this was not considered a suitable fix as it would yield near identical result as phase one. A major barrier to the research is a lack of reliable and available soils data. This is not peculiar to Chile by all means, but relying solely on the global FAO soils data would not produce the finer spatial granularity (ideally 10m) that is being sought. For this reason, the crop type parameters are crucial in improving spatial representation of the ecosystem models.

B. Re-training model parameters using local data

As mentioned under Objective A, a new database for regional crop parameters, and associated metadata and references, is being compiled. In addition, the project has developed a data set inventory that catalogues information from 27 different geospatial datasets that can be applied to ecosystem service modelling in the Chilean context. This database provides: the data set name in both Spanish and English; year or publication and any periodical refresh; a text description of the data; copyright and licensing information; location from which data can be sourced; data format; and other critical observations provided by the researchers relevant to the use of the data in landscape modelling. The project has also compiled a database of 41 chemicals applied to agricultural production systems, as these are considered to have a significant influence on ecosystem health and service quality. The database contains information that includes: the commercial name of the chemicals; active ingredients in the compound; concentration of active ingredients; the type of crop pest or disease it is used to treat; the advised concentration applied per hectare; the method of application; the number of applications required; the mode of application in relation to natural environmental variables (i.e. before or after precipitation events); methods for reducing impacts on the natural environment; environmental risks associated with the chemical; and other relevant observations useful for the research. Once the crop data has been compiled and undergone conclusive evidence quality assurance, it will be necessary to consider an appropriate method for incorporating the agricultural chemical information into the Bayesian belief network (BBN). This work is ongoing, and will follow pre-existing methods in the associated peer-reviewed literature that has been gathered. The method will calculate the average application, per crop type, per hectare, with the important caveat that chemicals are not applied uniformly in the landscape as they are used only in instances of pest or disease outbreak.

Due to the passage of time between the phases of work, some software compatibility issues arose, an important lesson gleaned from the activities. The open source SWAT model requires the GIS system (in this instance QGIS) and the operating system (Microsoft Windows 365) to be running at the same version. Due to internal server and system requirements at JNCC, QGIS was updated to 64 bit integers, whereas Microsoft operating systems have been maintained at 32 bit integers to keep them compatible with external financial software the organisation has embedded in their management systems. A workaround was implemented by JNCC IT Department, which took time and specialist knowledge. In addition, SWAT compatibility with R statistical software was also an issue, as the SWAT software does not run on the latest version of R. Therefore an older version of R was reinstalled to re-run the models.

C. Improving existing nodes of the Bayesian Belief Network

As mentioned above, the main focus has been to gain a better understanding of the soil, water, atmosphere and ecosystem interactions for different land use types. Understanding the impacts of climate change and drivers of water quality deterioration and water scarcity are the highest priorities, not only for vineyards, but for the agricultural sector as a whole, both in Chile and globally. It was decided therefore to focus on generating new data to support SWAT water and climate risk modelling, setting aside the fire risk and soil erosion models. This decision was made due to a number of factors. Firstly, analysis of the fire propensity modelling has shown that sensitivities are predominantly driven by proximity to human activities (i.e. habitation, transport infrastructure etc.) and to monoculture plantations of highly flammable pine and eucalyptus. Investing time in gathering information on other factors pertaining to fire risks (i.e. fuel loads, clearance of ground vegetation) would be highly labour intensive and unlikely to make

significant changes to the model. Secondly, the InVEST soil model was compared against the national soil loss data that is modelled and provided by CIREN. Whilst the soil model methods differed to some extent, the outputs were almost identical and the model developed by the project using InVEST and based upon the Copernicus landcover data and SRTM digital elevation model was perceived to give a better spatial resolution, and thus marginally more useful to guide landuse decisions at the individual field level. The agricultural chemical information will be a core component of improving the nodes pertaining to pesticide and fertiliser application. However, this will necessitate the improved crop data in order to generate a more accurate picture of impacts on ecosystem services at the landscape level based upon predicted chemical applications.

D. Developing unpopulated nodes of Bayesian Belief Network

The main objective here was to develop the BBN to provide a stronger indication of the role that the more 'natural' elements of the landscape provide in terms of ecosystem services to agriculture and wine production. As with many projects that employ the concept of natural capital, our team were specifically interested in the role that biodiversity plays in natural pest management practices (i.e. wild crop pest predators); the 'terroir' of the vineyard itself through the maintenance of the microbiome in soils and on the grapes themselves (i.e. soil fauna and wild yeasts); and the natural beauty interest provided by the landscape itself. This element of the research was predominantly driven by expert advice on the types of interactions that the fellowship research needed to explore, and to ascertain if and how these interactions can be modelled in a useful and effective manner.

During workshops held as part of phase one, vineyards noted the importance of the presence of Culpeo Foxes (*Dusicyon culpaeus*) to control the populations of introduced non-native rabbits that burrow beneath the vines and damage the antique plants. Research does indeed support the notion of this important predator-prey interaction; however the foxes are highly generalist species distributed throughout Chile. There is no specific habitat requirements that can be drawn upon to model presence / absence or the function foxes provide as controllers of lagomorph pests. Therefore, the BBN relies simply on a presence (yes) or absence (no) criteria in respect of this ecosystem service. One of the major factors governing this is the presence of domesticated or feral dogs, which are prevalent throughout Chile and create environmental impact issues in their own rights; according to anecdotal conversations held with protected area managers who control feral dog populations as part of their conservation management prescriptions.

The other key crop pest predator are parasitic wasps of the genus *Trichogramma* that prey upon the ovum of the vine moth which lays its eggs on the leaves of the vine plants. The genus has been studied extensively, and as well as wild species, these organisms are also released into agricultural areas as part of biocontrol programmes around the world. One of the issues in modelling the prevalence of the wasps, and the function they play in naturally occurring pest control (i.e. not mass transit and release) varies significantly due to a range of factors. These factors include *inter alia*: habitat types; structures of the plant upon which oviposition occurs; spacing and structure of the vines within the vineyard; plant surface structure and chemistry; plant volatiles and vegetation colour; and the interactions between the host plants and the parasitoids themselves (e.g. pollen availability affecting foraging behaviours of *Trichogramma*). Moreover, the distances travelled by foraging insects from patches of natural habitat are short (~10m), heavily affected by environmental factors such as precipitation and windspeed, and most long distance dispersal is via passive means that are difficult to quantify in a general sense at the landscape level. These myriad factors made it complex to devise a suitable logic chain within the BBN structure that could be used to model this ecosystem service. Fundamentally, the models produce 10m buffers around natural habitat as potential sources of naturally occurring *Trichogramma*, which is of limited value to land managers in terms of informing management interventions. Moving forward, developing a more comprehensive knowledge of the *Trichogramma* species present in Colchagua, and their ecology, would prove insightful into the use of this genus in biocontrol. This work is already underway in the UACh Agriculture and Food Science Faculty. See: Proyectos Fondecyt 2022-2026, Landscape and farm scale drivers of natural enemy resources and the effect on insect biological control, managed by Prof. Mauricio Gonzalez Chang < https://agrarias.uach.cl/proyectos-fcaa/>.

1. What were the major achievements of the fellowship? (up to three)

1. The CRP Fellowship enabled the project to significantly improve the evidence base that is now available to researchers working on better understanding the social-ecological-economic interplay between agricultural systems,

the regional communities that both benefit from, and are impacted by, industrial agriculture in Chile. This includes the geospatial data inventory, crop cover dataset, agricultural chemical inventory, and the crop phenology dataset.

2. Being able to collaborate closely with stakeholders on the ground in Chile made it possible to engage with a much broader range of stakeholders holding an interest in the project and the methods that we have developed. This included:

- Meetings with WWF-Chile to demonstrate the models and discuss the potential for such approaches to inform national and regional initiatives that include: Chilean National Restoration Plan (PNREP) 2021-30 < https://mma.gob.cl/wp-content/uploads/2021/11/Plan-Nacional-de-Restauracion-de-Paisajes-2021-2030.pdf>; the CBD-GBF 30x30 Target < https://www.iisd.org/articles/insight/global-biodiversity-framework-30x30-target>; and The Bonn Challenge < https://www.bonnchallenge.org/>. Subsequent discussions between WWF-Chile, WRI and JNCC have brought together regional organisations to better align activities taking place across Chile and Latin America under 30x30 and Bonn as part of the UN decade on restoration.

- Attending meetings and workshops with regional protected area managers through the regional CONAF network to better understand the objectives and needs of national protected area networks and their interest in ecosystem service assessments and ecosystem modelling.

- Meeting with owners of private protected areas in the Los Rios region to better understand how ecosystem service modelling can help meet their management and current / future funding requirements.

- Meeting with local government and forestry companies to better understand the statutory requirements that govern the forestry sector, including understanding and mitigating impacts caused by wood crop harvesting, and how the methods employed in our research aligns with operations within the Los Rios region and more wisely.

- Forging stronger links with the Association of Municipalities of the Valdivian Coastal Range <www.costalosrios.cl>

3. Disseminating our work via regional meetings and workshops and extending our work and networks has been a key achievement. I contributed to the ongoing Ecolapsus lecture series that is hosted by UACh. The series draws together early career researchers, post graduate staff, post-docs and teaching staff, with an hour lecture on the use of data and modelling tools in informing sustainable land management. This was particularly fruitful as many of the audience were unaware that much of the software and data are 'free to use' but require some time investment to learn how to use and adapt them for their own purposes. In addition, Dr. Godoy presented our project to an expert workshop hosted by the University of Chile in Santiago that looked at the use of the Copernicus satellite data in natural capital and ecosystems assessments. The presentations and conversations have been instrumental in growing our network and interest in the approaches developed through our work. This has led to a new project proposal being submitted to a Horizon Europe research and innovation action to develop prototype data services for dynamic ecosystem natural capital accounts based upon earth observation data. This project proposes two case study sites, one in Los Ros, Chile and the other in Magdalena Department, Colombia. Dr. Barbosa has been invited to consider being part of the project's external expert advisory body. The new contacts made through the CRP Fellowship enabled me to advocate Valdivia, Los Rios, as the proposed candidate sites and many new partners have provided letters of support for the project and indicated an interest to be part of the Advisory Board; hopefully strengthening the project's chances of being selected for funding.

Figures 1 to 3 below provide a snapshot of the activities I was able to engage with thanks to the support of the OECD CRP Fellowship.

Figure 1. Meetings with Raulintal management team, part of outreach to regional stakeholders with interest in natural capital application in private protected area management in Chile. Regional Conaf workshop identifying future needs for effective protected area management in Los Rios / Northern Patagonia.

Figure 2. Contributing to the Ecolapsus lecture series hosted by UACh (followed with free Valdivian beer!!!)

Figure 3. Dr. Godoy presenting our project to a regional conference on the use of Copernicus satellite data in natural capital and ecosystem service modelling for land management decisions.

2. Will there be any follow-up work?

There are two publications under discussion at present. Our immediate project team is working on a resubmission of a paper to Ecosystem Services journal. The original manuscript was rejected as reviewers felt the article failed to add significantly to the technical and non-technical reports that have been published during Phase One. Our idea to resubmit based-upon the stakeholder defined element is still under discussions. The paper has been hampered by the fact three of the original four analysts are no longer at JNCC.

On a more productive note, the team has written an online article that has been hosted on the IEB website <https://ieb-chile.cl/noticia/evaluan-servicios-de-ecosistemas-en-agroindustria-para-priorizar-su-conservacion/> which highlights the work undertaken, and signposts to the paper we have published in 2022 in the Journal of Applied Ecology that centres around the research we have undertaken. See: *Implementing ecosystem service assessments within agribusiness: Challenges and proposed solutions* <https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.14250>.

In addition, our team have been in conversation with colleagues from the Chilean National Congress Library and the University of Chile regarding a potential policy brief for Chilean decision makers that will outline the value of using earth observations in policy setting and monitoring effectiveness of interventions. As we see this as a broader topic than sustainable land management, we are waiting upon the completion of a separate project that has been working on increasing user uptake of earth observations in Latin America. The outputs from our viticulture work, combined with information gathered from the workshops looking at the use of EO in researching climate change, disaster preparedness, natural resource management, natural capital and ecosystem services, and marine ecosystems, will be drawn upon to produce this policy brief. See <https://jncc.gov.uk/our-work/copernicus-satellite-data-in-chile-and-latin-america/>.

As discussed previously, the project has not resulted in protected IPR, but the products that we have developed are certainly novel. The UN Statistics Department, amongst others (including the European Environment Agency) have called upon researchers and geospatial experts to work more closely with national statistics departments to better integrate EO into national natural capital accounts. The outputs we have developed have been key in addressing this call with the follow-up work to develop new natural capital Copernicus data services via Horizon Europe funds. Whilst we hold high hopes that our offer will be considered favourably, if unsuccessful, our cohort will seek to resubmit to other relevant funds as there is a global call from practitioners for such services to be brought online.

Following a change to the Executive Leadership Team at JNCC, the international strategy is being revised. To date, there is no clear sight as to what the international work portfolio of JNCC and other UK Government agencies will look like moving forward. In order to focus on the work developed through the CRP Fellowship, and elsewhere, I have made the decision to leave JNCC at the end of March 2023 to focus on the opportunities in Latin America, building on this work and the networks I have established. I now have residency in Brasil, where there is a growing interest in how natural capital and environmental economics can be mainstreamed into environmental policy, management and enforcement. Therefore, it is difficult at this stage to comment on, or commit to, future collaboration between JNCC and UACh. However, I personally will be continuing my work in Chile and intend to maintain close ties with Dr. Barbosa, her team, and the University of Austral de Chile.

3. 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?

The research contributes to the Programa Vino, Cambio Climático y Biodiversidad (VCCB, Wine, Climate Change and Biodiversity Programme) <https://vccb.cl/en/> which is a scientific initiative of the Institute of Ecology and Biodiversity and UACh. It models the ecosystem services of greatest importance to the wine industry of Colchagua Valley. Using a combination of satellite data, regional and global data sources, local knowledge and open source tools, the project produced ecosystem service delivery maps for the region, as well as an interactive VINES tool which allows vineyard managers to not only understand the level of ecosystem service delivery at the field level now and under climate change scenarios, but also to test how changes in their land management decisions contribute to the ecosystem service delivery.

The UK has a long-standing trading partnership with Chile, in 2017 Chile exported 9% of its wine to the United Kingdom to a value of US$203m. The total market value on Chilean wine in 2018 was US$2Bn. Between January 2018 and January 2019 UK consumers purchased 105 million bottles of Chilean wine, with sales amounting to GBP 720 million. This equals 9% of total UK still wine sales by volume and 8% by value. Bilateral trade between the two nations amounted to GBP 1.8 billion in 2017. Projects such as ours are critical to the UK and its trading partners in understanding how emerging science and technology can be translated for use by businesses to underpin sustainable supply chains that deliver long-term value, whilst protecting the ecosystems that support the global economy.

Besides the economic importance of wine production, the Colchagua Valley , located in central, forms part of the Chilean Mediterranean biome. The area plays a significant role in the productivity of Chile's agriculture and viticulture and is also considered a priority for biological conservation as it represents 16% of the continental surface of Chile, yet hosts 50% of flora and more than half of the country's endemic species.

The project demonstrates how open source Earth observation data and modelling software can be used in combination with commercial and local knowledge to develop a suite of user defined tools that help bring environmental data into corporate decision making processes. It has provided landscape-scale understanding of the habitats and the resulting benefits and trade-offs of ecosystem services from the perspective of primary producers, while also producing a tool to consider the implications of these factors at the scale of individual businesses.

4. How was this research relevant to:

- The objectives of the CRP?
- The CRP research theme?

The work supported by the CRP contributed to Central Theme 1 on managing natural capital by:

- demonstrating through easily interpretable models and tools how a healthy functioning landscape delivers a multitude of ecosystem services to producers, thus benefiting wider society. It also provided an interactive tool that land managers can interact with to better understand, risks, opportunities, impacts and dependencies on biodiversity, ecosystems and natural capital, as well as the sustainable agricultural practices that can help reduce harm to these critical systems;

- enabling phase two of the project to focus on soil, water, crop and climate interactions. The modelling is showing the risks of water stress under future climate scenarios, and those areas in the landscape most at risk from future drought conditions. Producers saw this element of our work in terms of both risk that it poses to current production and water demands, but also an opportunity to forward plan for land uses that are more suited to predicted future climate scenarios. This highlighted how modern management practices, coupled with available science and technology, can help address these threats and begin considering how to realise opportunities in a sustainable manner; and

- making it possible to engage more actively with other sectors, particularly the forest sector. We were able to meet with some of the largest forestry companies operating in Latin America, who have shown a great interest in our methods, and who have now gone on to support proposals to conduct follow-on phase three that will scale up the prototype not only in Chile, but also a Colombia. If funded, this project will focus on carbon, water and biodiversity ecosystem accounts in forests, wetlands and grasslands.

The work contributed to the objective of the CRP by:

- facilitating international co-operation among Chilean and British research scientists and institutions. In doing so, it has strengthened scientific knowledge and innovation by providing the means to demonstrate the value of earth observations and modelling in meeting the needs of land managers and producers and demonstrating how factors including natural ecosystems, biodiversity, and the predicted affects of climate change are material to production systems;

- providing valuable evidence and information to support decision makers, and strengthening the existing network of parties in Europe and Latin America with an interest in promoting the sustainable use of natural resources in food, agriculture, forestry and land management;

- improving the knowledge base and management tools to tackle global environmental change issues and their potential impact on food security, climate change and the inter-connectedness of UK and Chilean economies through trade and scientific co-operation.

5. Satisfaction

The Fellowship was different to what one envisioned when the proposal was submitted, due to the unforeseen outbreak of Covid-19 and the fallout of that globally defining event. Chile did not relax restrictions until 1 October, up until which point movement of people was restricted, and many Chileans were still working from home. My supervisor was also part of Chile's frontline efforts during the pandemic, meaning that priorities and time demands shifted from when our idea was first hatched in 2019. Nonetheless, our team reconvened and adjusted our approaches to ensure our time spent working together was fruitful and has led to exciting new opportunities to develop this field of work further with a broader set of partners and sectors in Europe and Latin America.

Without question, the Fellowship has unlocked opportunities and new collaboration that have created significant career benefits for me. For this I am extremely grateful to the OECD, the CRP Programme Board, and all of those who have made the resources available to support this activity. Not least of all, my excellent hosts at the University of Austral de Chile (UACh) whoa afforded me the utmost courtesy and support throughout my time working in Valdivia with them.

My only suggestion for improving the CRP would be to create a space for the Fellows themselves to interact and share experiences. I am unsure if there will be calls for presentations or dissemination in future, but that would be a nice touch to the programme.

6. Advertising the Co-operative Research Programme

I learned about the CRP via my Business Development Unit at JNCC. They provided a link to the CRP in an internal newsletter.

It could be possible to make the CRP more visible by asking people if they could be active on social media. There was no specific guidance on this, but it could be a wonderful way of getting real time updates on the activities people are undertaking.

The only issues were as a result of a global pandemic, which many teams globally had to manage and adapt to. The Fellowship would have had different outcomes had we followed directly on from our pilot phase work in 2019, but the work we did undertake was adapted to new challenges and opportunities and was a worthwhile endeavour.

-End-