Final report VISTA 2014

Development of a new automated tool for ecosystem service evaluation (EcoSET)

Project director: Kathy Willis and Vigdis Vandvik
Post-doc/ scholar: Sandra Nogué
Institution: University of Bergen/University of Oxford
Project duration: December 2011 – 30 November 2014 (3 years)
Technical contact person in Statoil: Dr Mathijs G. D. Smit
Division head: Christian Collin-Hansen
Project number: 6158

1. ½ A4 page with a popular presentation of the project (to be written by the scholar)

Humankind depends on nature. We need clean air to breathe, food to eat, and we need a healthy environment to live in. These goods and benefits that humans receive from the environment and the biological diversity (biodiversity) that it contains are often referred to as 'ecosystem services'. Landscapes, and different aspects of biodiversity, differ in the ecosystem services they provide. Our actions, whether it is to conserve a forest or to build a factory, affect ecosystem service provisioning. So, as the importance of ecosystem services is recognized, there is also a growing need for tools and models for mapping ecosystem services. Such tools will provide decision-makers and conservationists with spatially explicit information on ecosystem service provision and the effects of different land use options on those services.

In this project we developed a web-based tool for mapping ecosystem services that underpin human wellbeing. For example, pollination provides one of the most important ecosystem services as the vast mayority of plants, including important crops, are dependent on animals to produce their fruits and seeds. Cultural services and well-being are an example of a more subtle (yet important) ecosystem service that nature provides us. We connect with our natural environment in different ways, and we spend considerable resources to be in, or travel to, natural habitats or phenomena, such as the mountains or fjords, that we consider valuable for recreation and/or spiritual wellbeing.

2. **Have there been any changes in the objective/goals during the project period? Did you achieve what was promised in the project description? (to be written by the scholar)**

a) Achievements

The aim of this project was to develop an innovative web-based Ecosystem Service Tool (EcoSET) using novel algorithms and freely available datasets. This project was successfully completed on November 2014 and we are pleased to report that the algorithms behind the EcoSET tool have been finished and that the web interface will be fully deployed shortly. During the last three years we focused on data aquisition, selection, and algorithm design for three layers: pollination, cultural, and soil erosion ecosystem services. The data (e.g. species coordinates, flickr data points, etc) was generated by semi-automated algorithms on the development server, and stored by 1 degree tiles. Main results on ecosystem service layers are as follow:

Pollination

Development of the pollination algorithm has been completed and a manuscript describing pollination services in Europe is ready for submission (see publication list). We identified the European countries with higher pollination service delivery in their landscapes and we ranked bee species according to their potential to contribute to pollination service delivery to crops. In total 120,429 species occurrence data points were obtained. This data was then used to build and validate distribution models using Maxent (Phillips et al. 2006). In developing the species distribution models the following environmental covariates at 300 m pixel resolution were used: Land cover class (The European Environment Agency (EEA) 2006), elevation (Farr et al. 2007), mean annual temperature, temperature seasonality, total annual precipitation and precipitation seasonality. Climate data was obtained from Worldclim (Hijmans et al. 2005). Finally, we modelled the crop-bee interaction to indicate the present day potential pollination delivery (Fig.1).

Cultural services

In developing the cultural layer, the aim was to try and remotely determine the value that humans attribute to the landscape based on its 'visual' features – on the basis that a more visually stunning landscape is somewhere that people enjoy recreation and it provides greater cultural services. To do this we developed an algorithm for cultural service provision based on social media records through assessing flickr records (https://www.flickr.com) and the number of times certain landscapes are photographed. We have developed a query from the flickr API. To date we have obtained, 729,943 non-urban flickr records from across Europe for this layer. We found that the most appropriate statistical learning method to generate a "picture distribution models" is Maxent algorithm (Phillips et al. 2006). In this case, the distribution models relate "pictures" occurrence to environmental information such as: land cover class (EEA, 2006), elevation (Farr et al. 2007), mean annual temperature, temperature

seasonality, total annual precipitation and precipitation seasonality. We generated the spatial distribution of the collected pictures and showed the number of times certain landscapes are photographed across Europe. The results from the model are excellent with a model performed of AUC =0.93. The map in figure 2 shows the potential recreational amenity (ie potential supply of cultural service, not consumption). The scale can be interpreted as the conditional probability of a photo being taken and submitted to flickr at a location as a function of the environmental covariates at that location.

Soil erosion

The aim of this ecosystem service layer was to adapt an algorithm to detect the amount of soil protected by land cover. To do this, we used the Universal Soil Loss Equation (RUSLE) which is a widely used mathematical model that describes soil erosion processes (Renard *et al*, 1997). Figure 3 shows the greatest (in red) and the lowest (in green) amount of potential erosion prevented by the land cover.

Developing the infrastructure for the EcoSET website

The aim of the web-based tool is to provide a user friendly environment and a final pdf report containing styled maps of all ecosystem services for the targeted region of interest. To achieve this, we worked with Tessella, an international analytics, software services and consulting company based in Oxford (UK), to assist with the web site developement. So far, we have designed the web interface and processed and organized in 1 degree tiles all the ecosystem service data generated by the algorithms descrived above. The loading page can be found at the following webiste http://www.ecoset.ox.ac.uk (Fig.4).

Long-term environmental data and Ecosystem services

Current knowledge of the effects of drivers on ecosystem service provision are typically limited to those measured within the temporal limits of instrumental records (e.g. 50-100 years) despite the fact that many of these processes vary over much longer time periods. One of the objectives of the EcoSET project was to explore the changing nature of landscapes over time in order to lead to a more flexible view on how and where to manage ecosystem services.

The potential for incorporating long-term environmental data to provide a dynamic measure for ecosystem services has been recently published as a review paper in Quaternary Science Review (Jeffers *et al*, 2015). In this we examined the utility of palaeoecological records for: 1) providing proxies for ecosystem processes, services and goods in units that are relevant to modern ecosystem management; 2) determining how resilient these services are to key drivers of change, and 3) demonstrating how this information can be mapped over space and time to support sustainable natural resource planning.

MSc Thesis

One MSc thesis has been successfully submitted and defended by Ynghild Gilje Storhaug at the University of Bergen and co-supervised by Vigdis Vandvik and Sandra Nogué. The aim of the thesis was to quantify the pollination service delivery in apple orchards in Lofthus (western Norway) and to test the measurement of pollination ecosystem services at a local scale. Specifically we aimed to determine whether the landscape and biological features that we used in our algorithms to determine pollination abundance, were correct. In this project a total of 555 georeferenced pollinators (520 honey bees and 35 bumblebees) were collected from 22 farms across the landscape. Main results suggested that bumblebees are more likely to be present at higher elevations where forest is present. On the contrary, the honey bee's suitable conditions are predicted for the lowland areas and mainly in grasslands. These results suggest that to successfully validate our pollination output at a country level (and finally in Europe), we should plan a survey at a larger scale (e.g. Norway) in order to include the maximum representation of land-use types and number of pollinators.

Fieldwork

We have completed two field seasons to assess bee pollination in apple crops in Lofthus in Hardanger in collaboration with Bioforsk, during June 2013-2014 (Fig. 5). Our aim was twofold: 1) to collect local pollinator data to validate the EcoSET pollination layer (see above), and 2) to establish a long-term pollination survey in Hardanger. This successful study has been and **addition** to the EcoSET project.

b) Changes in the objective/goals during the project period

We have not made major changes in objectives and goals but we have made some strategic decisions in order to improve the timetable and the final results. Our first strategic decision was to focus on three important ecosystem services in European landscapes as test cases for the tool (pollination, cultural, and soil erosion) i.e. we decided not to include water regulation and carbon storage. This was done to avoid data quality issues. We have also expanded the project aims by completing two fieldwork seasons to obtain high quality pollination data in the field and field test the output from the tool at local scale.

3. Publications (scholar) during the project period

1. **Nogué, S**; Long, P; Eycott, de Nascimento, L; Fernández-Palacios, J.M; Vandvik, V. & Willis, K.J. 'Pollination service delivery for European crops: challenges and opportunities (to be submitted). Ecological Economics.

2. Jeffers, L; **Nogué, S.** & Willis K.J. (2015) How sustainable are ecosystem services in the face of environmental change? Evidence from the past. Quaternary Science Reviews. 112, 17-32.

3. de Nascimento, L; **Nogué, S**, J.M; Fernández-Lugo, S; Méndez, J; Otto, R; Whittaker, R.J; Willis, K.J. & Fernández-Palacios, J.M. (2015) Modern pollen rain in Canary Island ecosystems and its implications for the interpretation of fossil records. Review of Palynology and Palaeoecology. 214, 27-39

4. Bhagwat, S.A; **Nogué, S.** & Willis, K.J. (in review) Cultural drivers of reforestation in tropical forest groves of the Western Ghats of India. Forest Ecology and Management. 329, 393-400.

5. Seddon, A.W.R. & the **Palaeo50** Working Group. (2014) Looking forward through the past: identification of 50 priority research questions in palaeoecology. Journal of Ecology, 102(1), 256–267.

6. **Nogué, S**; de Nascimento, L; Fernández-Palacios, J.M; Whittaker, R.J. & Wills, K.J. (2013) The ancient relict forests of La Gomera, Canary Islands, and their sensitivity to environmental climate change. Journal of Ecology, 101, 368–377. ***editors choice (February 2013).***

7. Rull, V; Montoya, E; **Nogué, S** , Vegas-Vilarrúbia, T. & Safont, E. (2013) Ecological paleoecology in the neotropical Gran Sabana region: long-term records of vegetation dynamics as a basis for ecological hypothesis testing. Perspectives in Plant Ecology, Evolution and Systematics, 15(6), 338-359. ***editors choice (2014).***

8. Ochoa-Ochoa,L; Jarzyna, M.A; Lira-Noriega, A; **Nogué, S**; Santos, A.M.C; Tovar, C; Stevens, G; Hortal, J. & Field, R. (2013). Research frontiers of early-career biogeographers. Frontiers of Biogeography, 5(3), 161-162.

9. **Nogué, S**; Rull, V. & Vegas-Vilarrúbia, T. (2013) Elevation gradients in the neotropical table mountains: patterns of endemism and implications for conservation. Diversity and Distributions, 19 (7), 676-687.

10. Bashgwat, S.A; **Nogué, S.** & Willis, K.J. (2012) Resilience of the Western Ghats forest to 7500 years of climatic change. Biological Conservation, 154, 108-117.

11. Vegas-Vilarrúbia, T; **Nogué, S.** & Rull, V (2012) Global warming, habitat shifts and potential refugia for biodiversity conservation in the neotropical Guayana Highlands. Biological Conservation, 152, 159–168.

12. **Nogué, S**; Santos, A.M; Sanders, M. & Ochoa-Ochoa, L. (2012) Discussing the last advances in Biogeography with the young biogeographers. Frontiers of Biogeography, 3(4), 133-136.

4. Reflections on continuation of the project (to be written by the project director)

The overall aim of this project was to develop an innovative tool allowing assessment of the ecosystem service consequences of the loss of ecologically valuable land in Europe. A key feature of the tool is that it is scalable, and so it can be used on very local to continental scales. Thus, it can support decision-making both very locally and enable questions such as what components of this landscape should we protect? Where installations such as roads or factories should be placed? How can ecosystem service delivery be promoted? The aim was also to develop an approach that was applicable on local to regional scales. The current project has provided a proof of concept. We are now planning future work to improve and to further develop the EcoSET tool. This will involve the following:

1) In order to expand the Ecosystem service assessment beyond Europe we will include new datasets and GIS layers to improve the quality and the geographical scale of the EcoSET tool (the eventual goal is to have the tool working at a 30m resolution globally).

2) We will run workshops with statekholders (landowners and businesses) in different European countries to explore how they would utilise the tools and technologies we develop.

3) We are working towards publications on: the cultural service algorithm, and the EcoSET tool.

4) The EcoSET website will be fully available including the webserver to process jobs and accesses a dedicated data server.

5. References

Farr, T.G., Rosen, P.A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., Alsdorf, D., 2007. The Shuttle Radar Topography Mission. Reviews of Geophysics 45, RG2004.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A., 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25, 1965-1978.

Hoehn, P., Tscharntke, T., Tylianakis, J.M., Steffan-Dewenter, I., 2008. Functional group diversity of bee pollinators increases crop yield. Proceedings of the Royal Society B: Biological Sciences 275, 2283-2291.

Phillips, S.J., Anderson, R.P., Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190, 231-259.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder, 1997, Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE), Agricultural Handbook, 703. U.S. Government Printing Office, Washington, D.

5. Figures

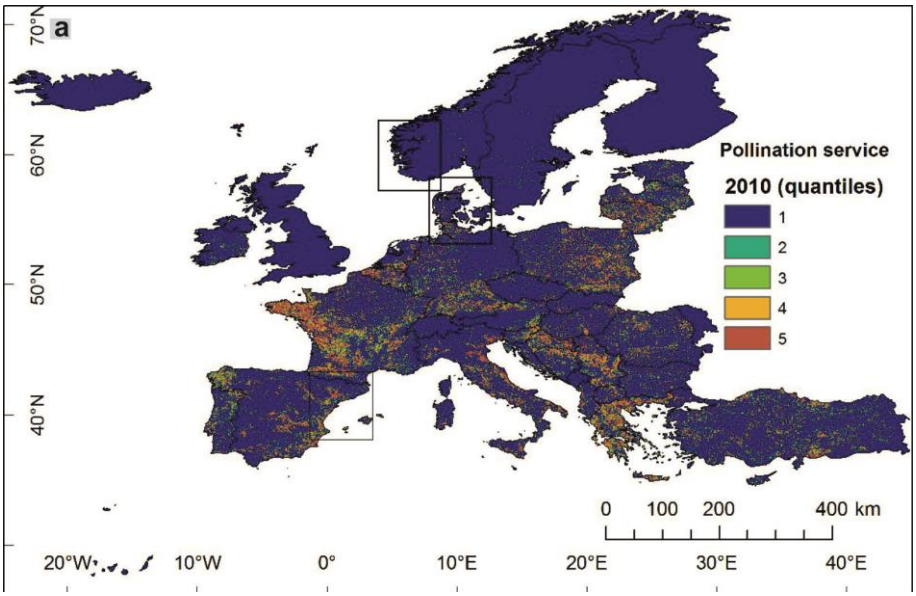

Figure 1: Relative pollination service delivery for Europe for complex cultivated pattern crops and fruit tree and berry plantation

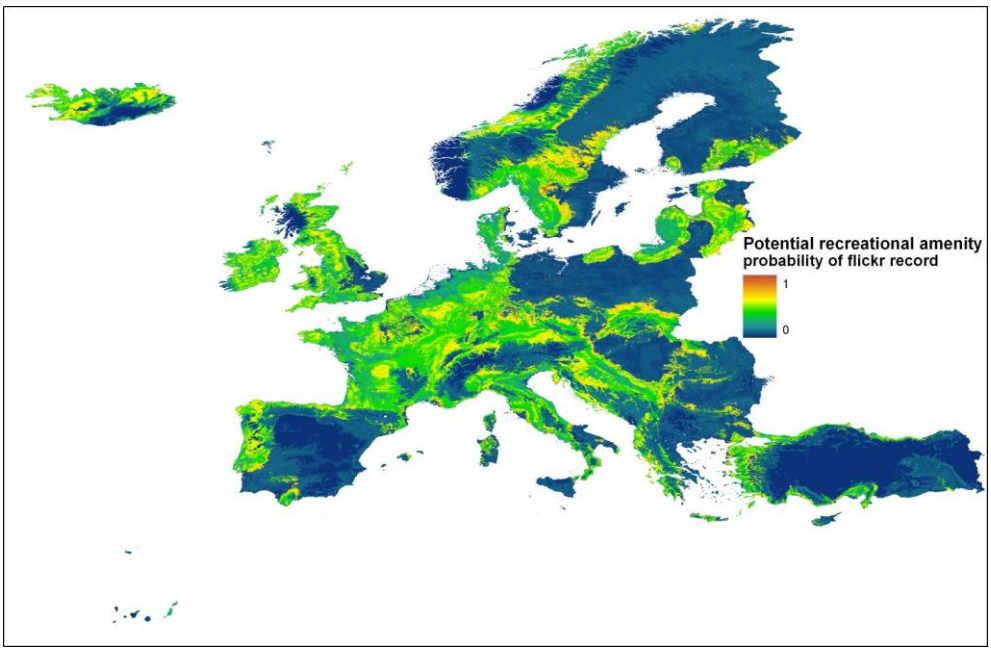

Figure 2. Relative cultural service delivery for Europe.

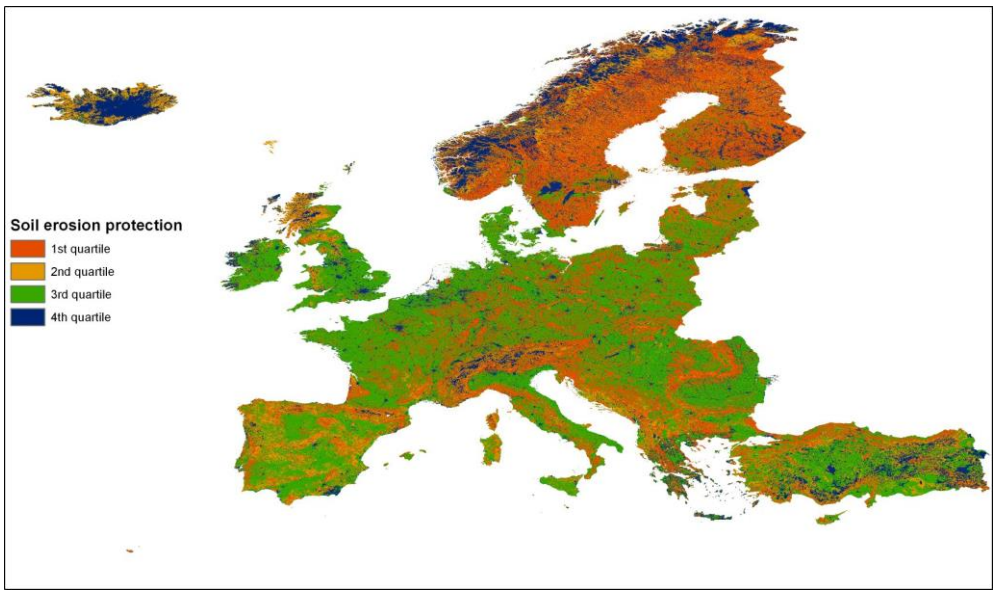

Figure 3. Soil erosion protection for Europe.

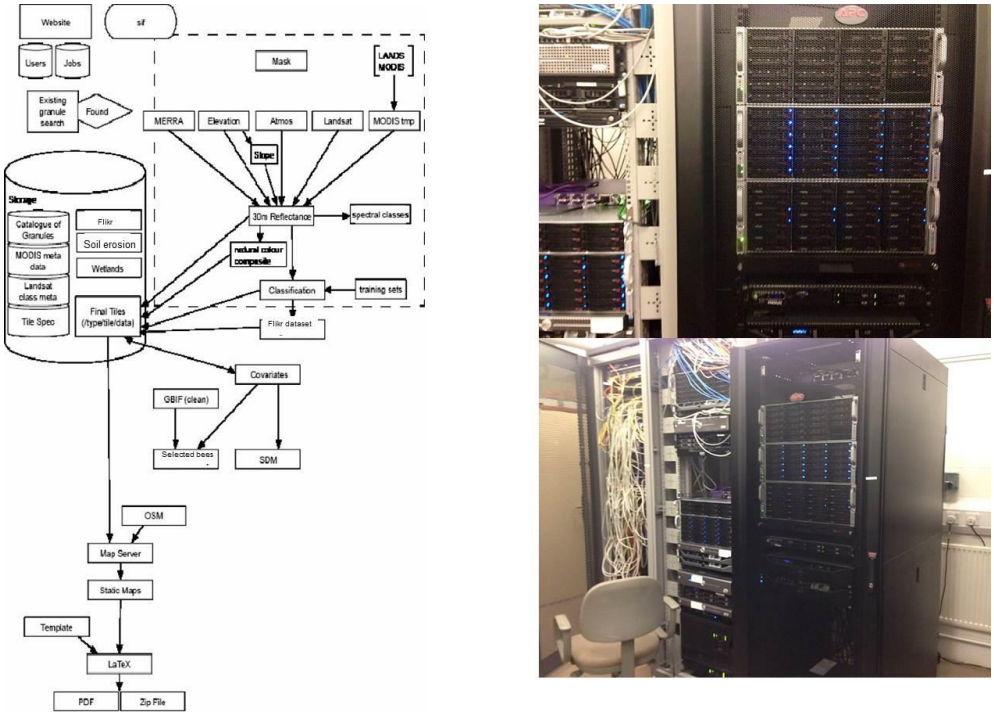

Figure 4. Summary of the main data processing flow in EcoSET.

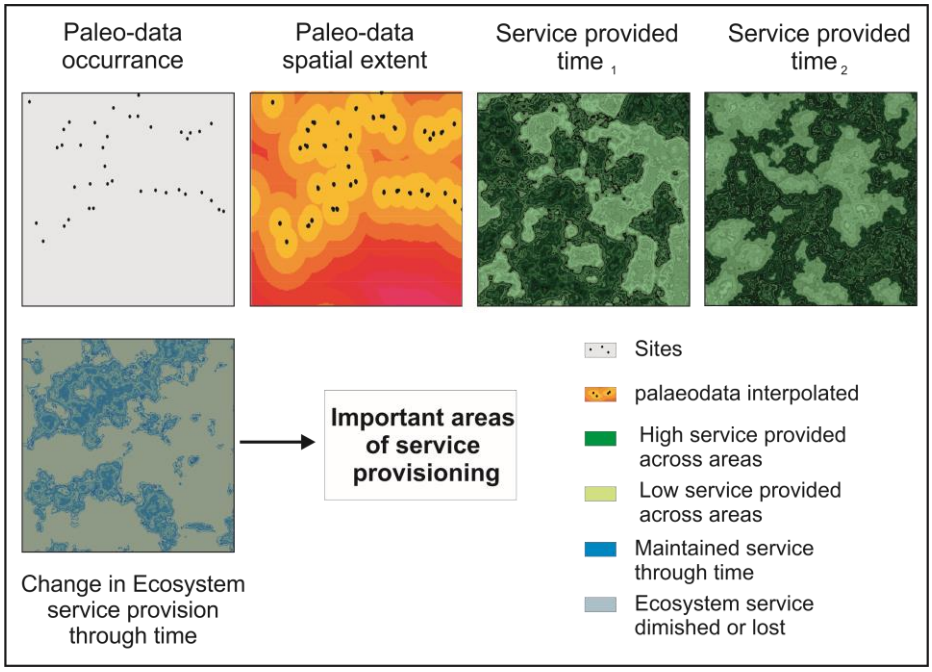

Figure 5. Summary of how to include palaeoecological data into the Ecosystem service framework

Figure 6. Apple crops in Lofthus.