(Projects submitting final reports after 1 January 2014 must use this format.)

LIFE Project Number

<LIFE12 ENV/UK/000473>

MIDTERM Report

Covering the project activities from 01/07/2013 to 31/7/2016

Reporting Date

<12/12/2016>

LIFE+ PROJECT NAME or Acronym

< NaturEtrade >

[Redacted version]

1. List of contents

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Executive Summary (maximum 5 pages)

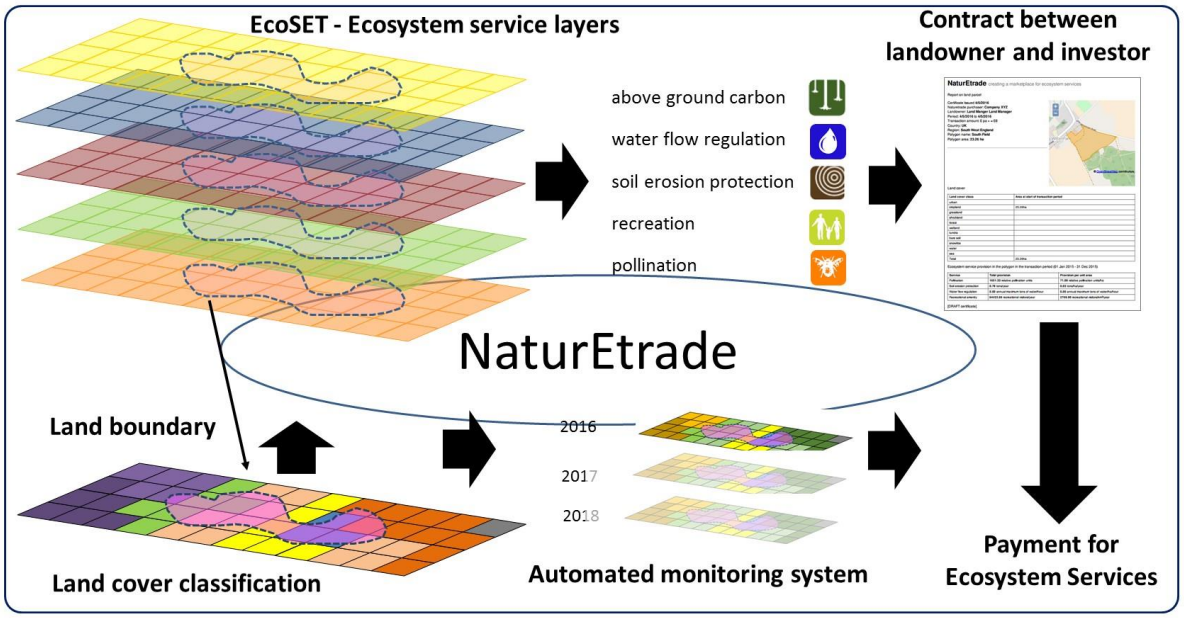
One of the greatest threats to the global environment and the sustainable management of natural capital is land-use change (Jetz et al., 2007). Private landowners and government face enormous incentives to sell and convert ecologically diverse land. The scale of this land conversion is significant: in the European Union alone, around 1500 hectares of ecologically-rich land are lost every day to changes in infrastructure and urbanisation (Uhel, 2006).

Land use directly affects key ecosystem services i.e. services provided by the natural environment that benefit people. These include the familiar food, fibre and fuel provision and the cultural services that provide benefits to people through recreation and cultural appreciation of nature, but also regulating and supporting services such as the regulation of the climate, purification of air and water, flood protection, soil formation and nutrient cycling. These services are in decline worldwide. Global land use changes were conservatively estimated to have resulted in a loss of ecosystem services worth $4.3 - $20.2 trillion per year (Costanza, 2014).

Much of the debate around the mitigation of natural capital loss assumes that there are not only scientifically rigorous tools to measure and monitor ecosystem services, but also a suitable mechanism to determine their economic cost. However, this is not the case. There are virtually no tools or mechanisms to assess ecosystem services at the landscape level, particularly time-efficient tools that can be used by non-specialists including landowners, businesses and governments, and no international, transparent trading platform where sellers and buyers can directly engage in transactions involving protection and improvement of

ecosystem services (Masden et al., 2011). As a consequence, conversion of ecologically-rich land to other uses continues to be the easiest and most profitable option for large numbers of landowners, fuelling the ever-increasing loss of natural resources.

Figure 1 Schematic of NaturEtrade



NaturEtrade is a web-based, scalable marketplace for ecosystem services (Figure 1). By combining a state-of-the-art scientific knowledge base and cost-effective satellite technology with rigorous economic theory of market design, we develop a digital marketplace that can be deployed anywhere in the world in order to mitigate the destruction of valuable ecosystems.

Measuring ecosystem services

In order to allow transactions in ecosystem services to be scalable it is necessary to produce digital spatial data about the state of the environment which is accurate, consistent and at a spatial resolution and temporal frequency which is relevant to individual landowners.

The approach we have taken is to use raw satellite and other environmental data which are available free of charge in the public domain and which we are able to modify and redistribute for any purpose (including commercial purposes). We then process these data using latest published algorithms to produce environmental datasets including land cover maps and maps of ecosystem services which are stored and then exposed to users through a simple and intuitive web interface (www.naturetrade.ox.ac.uk). Currently, we are producing environmental datasets for Europe at 30m spatial resolution.

We identify land cover classes: urban, cropland, grassland, shrubland, forest, wetland, bare soil, snow/ice, and water. By repeating this classification procedure every three months with new observations, it is possible to accurately detect land cover change.

Building upon the land cover maps, we have developed algorithms to produce maps of the amount of ecosystem services which are provided across the landscape in appropriate physical units. The five services we currently consider are:

- water flow regulation
- soil erosion protection
- crop pollination
- carbon in above-ground biomass
- recreational amenity

Market design

NaturEtrade overcomes transaction costs and contractual issues present in many PES systems:

The use of satellite technology and centralised IT infrastructure allows for virtually costless monitoring and measurement of ecosystem services. This set-up substantially reduces transaction costs between parties.

NaturEtrade has been integrated with Land Registry data in the United Kingdom allowing clear identification of property owners. This means that dispute resolution rules are straightforward and landowners are only able to contract land under their direct management into ecosystem service contracts. NaturEtrade could integrate any national or subnational land registry in the EU (INSPIRE directive) or elsewhere in the world.

Current and future market design

The marketplace is currently set up in a highly intuitive manner. A landowner (a seller) selects the plot she wants to "sell" and offers a take-it-or-leave-it price in return for preserving the current land cover on the plot for a fixed term. For simplicity, we have restricted the term to one year. The buyer is able to select any offers and enter into contracts immediately. If the land cover on the plot does not change after a year, the landowner is paid the agreed price. We envision a gradual evolution of NaturEtrade to a regular auction system, clearing the market through a centralised bidding process every three months. A key issue we will address is to allow buyers to bid on multiple plots of land simultaneously; we will also explore whether sellers could trade parcels of their land to different buyers. These kinds of combinatorial auctions with complex constraints are frequently used in practice (e.g. in allocating spectrum, see Milgrom and Segal, 2015), but are still a novelty in ecosystem protection (one outstanding example is the Native Vegetation Exchanged in Australia designed by Nemes et al. (2008), but never implemented).

Policy landscape and view ahead

Governments have already implicitly committed to serious efforts in ecosystem service protection: for example, the UK Natural Capital Committee has recommended no net loss of biodiversity in England by 2020 (Natural Capital Committee, 2015). Government regulation can certainly help in driving more widespread adoption of payment for ecosystem services and offsetting schemes. It is clear that the scientific tools underpinning NaturEtrade can, in fact, be used in a variety of regulatory and decision-making settings even without an explicit commitment to its market mechanism. For example, they can support policy makers in decisions involving local government investments in ecosystem services or for site selection and monitoring in REDD+ projects. Moreover, NaturEtrade raises awareness about

ecosystem service degradation for individual landowners as well as private companies and investors. As such, we expect NaturEtrade to play a key role in ecosystem protection and restoration around the world.

2. Introduction (1 page)

- ***Description of background, problem and objectives***
  - ***Environmental problem/issue addressed***

One of the greatest threats to the global environment and the sustainable management of natural capital is land-use change. Landowners (private, government, or other) face great incentives to convert ecologically-diverse land. The scale of this land conversion is significant. In the European Union, around 1500 hectares of ecologically-rich land are estimated to be lost every day to changes in infrastructure and urbanisation.

Land use directly affects key ecosystem services i.e. the direct and indirect contributions of the natural environment to human wellbeing, sometimes also called 'ecosystem benefits'.
These include the familiar food, fibre and fuel provision and the cultural services that provide benefits to people through recreation and cultural appreciation of nature, but also regulating and supporting services such as the regulation of the climate, purification of air and water, flood protection, soil formation and nutrient cycling. Globally, land use changes have resulted in a loss of ecosystem services worth $4.3 - $20.2 trillion per year.

Much of the debate around the mitigation of natural capital loss assumes that there are not only scientifically rigorous tools to measure and monitor ecosystem services, but also a suitable mechanism to determine their economic cost. However, this is not the case. There are virtually no tools or mechanisms to assess ecosystem services at the landscape level, particularly time-efficient tools that can be used by non-specialists including landowners, businesses and governments, and no international, transparent trading platform where sellers and buyers can directly engage in transactions involving protection and improvement of ecosystem services. NaturEtrade is conceived as a project that aims to introduce such a tool and test it in selected countries of the EU with landowners.
NaturEtrade is a web-based, scalable marketplace for ecosystem services. It combines a robust scientific knowledge base and cost-effective satellite technology with rigorous economic theory of market design to develop a digital marketplace that can be used by landowners and managers and businesses with a stake in conserving ecosystems in order to mitigate the destruction of valuable ecosystems. The project will be tested in the EU, where state-supported financial systems are in place for environmental protection, but the tool is designed to work anywhere in the world and is independent of such government schemes.

  - ***Outline the hypothesis to be demonstrated / verified by the project***

1. A web-based tool can be used by individuals with no prior technical expertise to determine the ecosystem services of any parcel of land anywhere in the EU at a 100m resolution.
2. Landowners and managers and businesses with an interest in conserving the environment and/or ensuring continuance of ecosystem services will participate in

a web-based trading mechanism (available in full on mobile devices as well as desktop computers) that links buyers and sellers via contracts of payments for conserved ecosystem services.
3. Using a web-based ecosystem services trading tool will reduce annual rates of conversion of ecologically diverse land relative to baseline rates of change.

- ***Description of the technical / methodological solution***

We locate reliable, raw satellite and other environmental data, which are available free of charge in the public domain and have global coverage (or at least EC-wide coverage) and which we are able to modify and redistribute for any purpose (including commercial purposes). We process these data using peer-reviewed, published algorithms to produce environmental datasets including land cover maps and maps of ecosystem services which are stored on secure servers in the University of Oxford. We expose these datasets to participants (landowners and managers and businesses) through a simple web interface. Landowning participants map their land parcels by drawing polygons (automatic process where land registry polygons are made available to our project) and the ecosystem services of the parcels are determined automatically. These can be viewed by prospective buyers of ecosystem services. A search function allows prospective buyers to look for parcels in a location of interest or with particular ecosystem service attributes.

- ***Expected results and environmental benefits***

The project will demonstrate that ecosystem services can be traded on an open market with benefits to landowners (selling) and businesses (buying) ecosystem services. The project will demonstrate the practical possibilities of evaluating ecosystem services by harnessing existing land-cover and ecosystem service data in an analytical tool that utilises complex algorithms to assign ecosystem values to parcels of land that are not measured directly in the field and which require no technical expertise on the part of the buyer or seller. The project hopes to demonstrate that biodiversity losses can be reduced by engagement with the project, either directly through trading or through using the assessment tools to monitor ecosystem service changes over time on parcels of land within the target countries.

– **Expected longer term results**

The project will help reduce biodiversity loss within the target countries and more widely in the EC. The demonstration project will show how web-based ecosystem service assessment can be achieved with no necessity to have environmental experts taking measurements on the ground. The project will demonstrate an economically attractive alternative to long-term field monitoring by harnessing the power of big data that is freely available. The project will engage with policy-makers in addition to landowners to scope the potential for using the tool as a policy instrument for monitoring, reporting and evaluating the consequences to ecosystem services of landuse changes. The five ecosystem services we have selected to demonstrate proof of concept can be readily augmented to cover others considered of societal importance. Much of the success of the demonstration project depends on the ability to attract users, and this will be a challenge given our very small marketing budget allocation, but the potential for the efficacy of the technical system we develop can be demonstrated from first principles and we have

designed the tool so that the assessment component could potentially be operated separately from the trading component as a policy instrument.

3. Administrative part (maximum 3 pages)

4.1 Description of the management system

- ***Description and schematic presentation of working method, including overview of:***
  - ***project phases***

  There are five distinct, but interlinked project phases:

  1. Creation of a web-based tool that can assess the uploaded parcels of land anywhere in the EU and determine the ecological potential /ecosystem services that they contain;

  2. Establishment of a web-based trading platform, where parcels of land and the ecosystem services they provide (as identified in (1)) can be traded;

  3. Development of standard contracts, a land verification system and an economic structure for the trading platform;

  4. Engaging with potential users of the tool by raising awareness amongst landowners and businesses of environmental problems, and the potential benefits of engaging with this project to understand ecosystem services provided by land and minimise loss of these services over time.

  5. Determination of whether engaging with the project can reduce loss of ecologically diverse land the case-study regions and comparing the amount of land-use change in these regions before and after the tools and technologies have been introduced.

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		2013			2014				2015				2016				2017				2018	
Action	Sub-Actions (Indicators of progres	Jul	Oct	Dec	Apr	Jul	Oct	Dec	Apr	Jul	Oct	Dec	Apr	Jul	Oct	Dec	Apr	Jul	Oct	Dec	Apr	Jul
B1:Development of EcoSET	1 Data acquisition for ecosystem service layers					(M1)								M1								
B1:Development of EcoSET	2Adaptation of the ecological layers from LEFT							(M2)				M2										
B1:Development of EcoSET	3Development of models, algorithms and datasets									(M3)		M3										
B1:Development of EcoSET	4Automation of the EcoSET tool													M4								
B1:Development of EcoSET	5Completion of GIS web-based tool (EcoSET)													D1								
B1:Development of EcoSET	6Production of report detailing design of EcoSET													D2								
B2: Creation of naturEtrade	1Design and set-up of NaturEtrade website		M5	D3																		
B2: Creation of naturEtrade	2Development of mobile data capture device					D4																
B2: Creation of naturEtrade	3Development of NaturEtrade database structure					M6																
B2: Creation of naturEtrade	4Linking EcoSET and NaturEtrade												M7									
B2: Creation of naturEtrade	5Interface system linking sellers & buyers												M8									
B2: Creation of naturEtrade	6Pilot tests of NaturEtrade													M9								
B2: Creation of naturEtrade	7Modifications to NaturEtrade after feedback									XMi												
B3: Standard contracts/verificatior	1Existing contracts for ES reviewed					M10																
B3: Standard contracts/verificatior	2Governance arrangements devised					[XDii]										XDii						
B3: Standard contracts/verificatior	3Develop & market testing of pilot contracts								(M11)	(D5)						M11 &D5						
B3: Standard contracts/verificatior	4Contracts integrated into NaturEtrade															M12						
B3: Standard contracts/verificatior	5Automated land verification system developed													(D6)			D6					
B3: Standard contracts/verificatior	6Database linkage between NaturEtrade and land verification system													(D7)			D7					
C1: Monitoring of impact of EcoSE	1Rates of land-use change determined									(M13)						M13						
C1: Monitoring of impact of EcoSE	2Regions for workshops selected									(M14)		M14										
C1: Monitoring of impact of EcoSE	3Workshops run in selected regions for landowners									[XDiii]								XDiii				
C1: Monitoring of impact of EcoSE	4Report on workshops														(D8)				D8			
C1: Monitoring of impact of EcoSE	5Assessment of land-use change & trading													[XDiv]					XDiv			
C1: Monitoring of impact of EcoSE	6Monitoring of social impact & equality - (Report)																					D20
C1: Monitoring of impact of EcoSE	7Report on success of trading and uptake																					D9
D1: Dissemination and communic	1Web-based survey created																					
D1: Dissemination and communic	2Articles published in relevant media outlets														M15					D10		
D1: Dissemination and communic	3Establishment of stakeholder database					XMii																
D1: Dissemination and communic	4Workshops run for potential buyers of ES										XDv											
D1: Dissemination and communic	5Knowledge exchange workshops run										XDvi											
D1: Dissemination and communic	6Report on result of networking activities																	D12				
D1: Dissemination and communic	7Report on effectiveness of communcation & dissemination activities																	D13				
D1: Dissemination and communic	8Regular additions to database and tool uptake																					
E1: project mgt & monitoring	1Project milestones completed																					
E1: project mgt & monitoring	2Project reports delieverd				(D14)		D14		(D15)		D15			(D16)		D16		D17				D18
E1: project mgt & monitoring	3Products running and available for use																					
E2: After-life communication plan	1Development of After-life communication plan																					D19

Table 1 Activities in each action, with associated milestones and deliverables

- *activities and tasks per phases*

Table 1 shows the amended project phases and tasks, with timelines for completion of each milestone and deliverable identified in the original project Agreement. Milestones are shown in pink, Deliverables in yellow. Pale pink indicates original dates for Milestones; pale yellow indicates original dates for Deliverables. Grey cells, marked 'XMi','XDi', etc. indicate milestones and deliverables implied in the text of the Grant Agreement but not originally listed in the tables of milestones and deliverables. Some of these run over longer periods of time, and not shown as single end-dates. **Error! Reference source not found.**shows the original deliverable and milestone tables from the GA, any amended dates, and the dates that the deliverable has been transmitted to the EC in the Inception or Progress report, where appropriate. New milestones and deliverables are also included. Modifications came about as a result of practical experience working on the project and realising that we could improve delivery of project objectives with either more time to work on some of the tasks, or a more logical sequence of task delivery. Changes have been discussed with our monitor (Lynne Barratt, Neemo) and noted in previous Reports to the EC (Inception Report - 04/08/2014, and Progress report - 03/08/2015). Explanations for alterations are outlined in the main body of the report.

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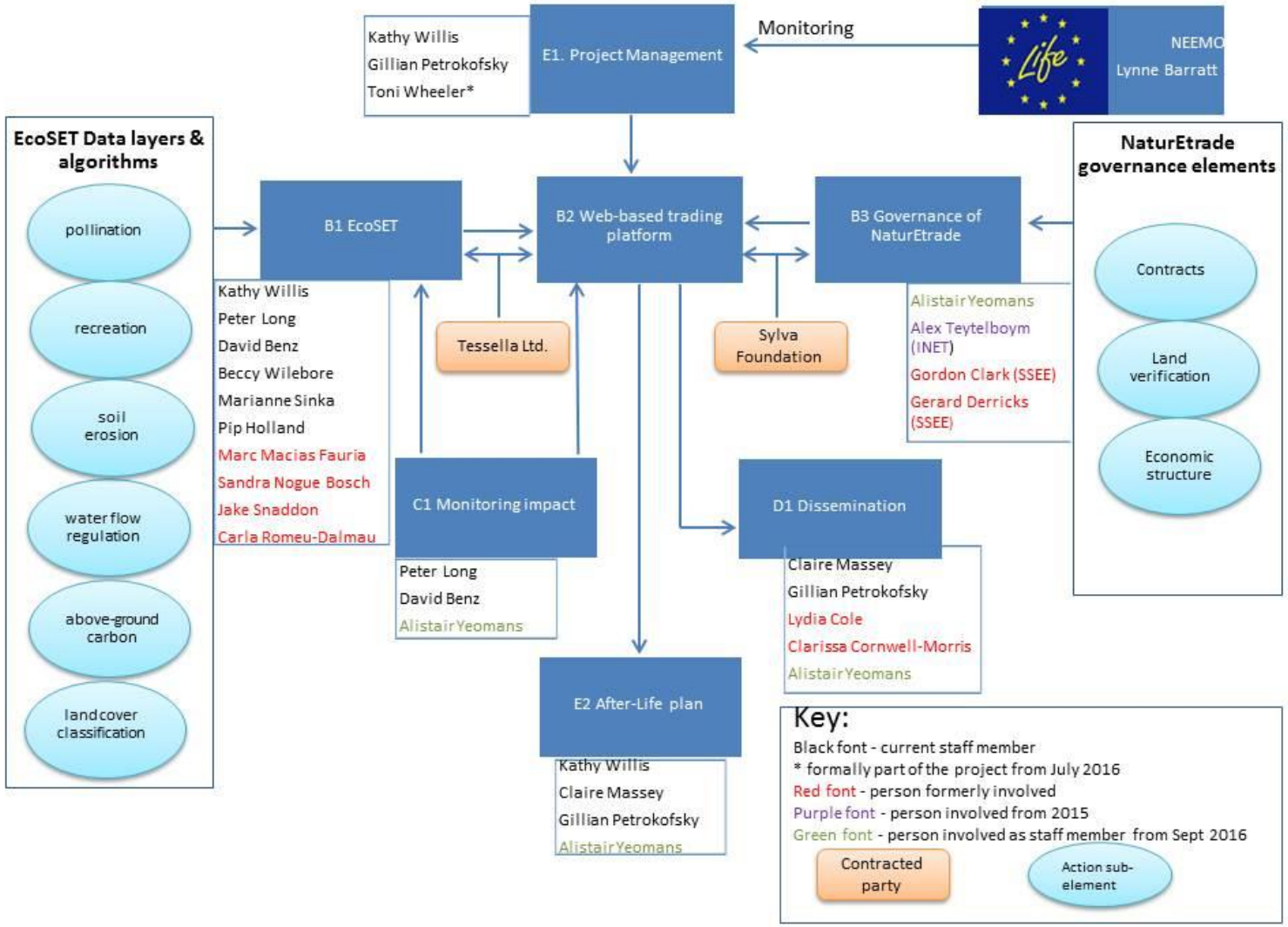
Figure 2 Organigramme of NaturEtrade project



- *planning*

Figure 2 shows the relationships between project tasks and includes the names of people working on them (or who have worked on them at earlier stages of the project). Informal team meetings are timetabled for Friday mornings in the Biodiversity Institute and held whenever there are new developments, technical problems, or other significant points for discussion. On average we meet fortnightly during term time and at least once outside term time. Meetings are co-ordinated by the Project Manager and involve Kathy Willis and other members of the research group working on ecosystem services (B1), monitoring (C1), and communication and dissemination (D1), and Alistair Yeomans of the Sylva Foundation, working on the web-based trading platform (B2) and governance aspects of NaturEtrade (B3), replacing most of the tasks originally allocated to the Smith School of Environment & Enterprise (SSEE) in B3.

Since 2015 most meetings have included Alex Teytelboym of the Oxford Institute for New Economic Thinking (INET), who has taken an interest in our project and helped us conceptualise the market. He joined by Skype a monitoring visit from Lynne Barratt in 2016. To that extent, he has replaced tasks originally allocated to SSEE for work in B3. Although he is shown on the organigramme, as an important contributor, he is not, at this stage, included in the financial reports, owing to reluctance on the part of his Department to submit timesheets for work that would be counted as matched time by the University for EC funds. We may be able to resolve this matter in due course and include him for budget purposes. Occasional Skype meetings have been held to include Scott Kominers, a Junior research Fellow at Harvard University and a Visiting Fellow at INET, to discuss elements of B3. He is not paid by University of Oxford and is not therefore considered part of the project team: he acts as an academic advisor to B3.

The budget is reviewed monthly by the project management team (E1) with Toni Wheeler, Grants Officer in Zoology, who liaises with the central Grants office of the University. The After-life plan (E2) has been discussed in meetings with Oxford University Innovation Ltd. (OUI) and with the University legal service. Figure 1 shows the relationship between different Actions and main personnel involved in each Action. In practice, all members of the project participate in discussions about any Action. The trade-off between time taken for meetings and greater awareness of the project as a whole is felt to be positive. It means that individual team members are able to help problem solving and take advantage of opportunities to demonstrate the project to external parties with more confidence and greater flexibility than would be the case if we had less understanding of Action elements and problems.
Email and Dropbox continue to be the main means of internal communication outside team meetings. Details of work progress, meetings attended, relevant academic papers, presentations, photographs, and discussion documents are posted there with full access to all.

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– *Description of changes due to amendments to the Grant Agreement.*

No changes made to the Grant Agreement

4.2 Evaluation of the management system

Progress on all Actions has been steady and mostly in line with our projections. Work on B3 has progressed more effectively since moving tasks from SSEE to the Sylva Foundation, whose contribution to the project has been key to the success to date. We indicated in the Progress

Report (dated 03/08/2015) that we would be seeking a change in the Grant Agreement in respect of our other contracted party, the Sylva Foundation. However, we have overcome the need for such a change with a simpler solution that will involve bringing one of Sylva's staff members, Alistair Yeomans, into the research group on a part-time contract until the end of the project, under the direct management leadership of Kathy Willis. The alteration to his contract with the Sylva Foundation was agreed by their Board of Trustees. Both parties agree that there are considerable efficiency gains for the project and delivery of the B3 tasks that had hitherto held up work on B2 undertaken by the Sylva Foundation. The Sylva Foundation will continue to deliver the original set of tasks outlined in their contract. We have also made much greater progress on developing thinking for the market side of the project since moving tasks from SSEE to INET.

In view of this, we have no partnership agreements with external parties; all parties are either within the University of Oxford or sub-contractors.

4.2.1. Communication with the Commission and Monitoring team.

We have had excellent communication with Lynne Barratt of NEEMO, our Monitoring unit mentor. She has suggested linkages with other LIFE+ projects doing related work, which we have followed up and identified potentially valuable collaboration. We have communicated with the Commission to date through reports and receipt of responses to these Reports. No problems encountered. We had a mission visit from the EC in November 2016 (just before submission of this report) and would like to record our thanks to them for their interest and guidance. We found the visit extremely helpful.

4. Technical part (maximum 50 pages)

5.1. Technical progress, per task

This section concerns all project tasks except for:

- "project management" which is dealt with in the administrative part (section 4) and
- "dissemination", which is dealt with in section 5.2

In this section you should describe **what and how** has been done regarding the different technical/substantial components of the project (such as research, fieldwork, construction). You should indicate what has been done regarding each task (subtasks if appropriate) but avoid describing the objectives and targets as such. The description of the work done has to be sufficient to allow a good understanding of the project without a need to refer to the annexes. The technical details, however, should be given in the annexes. Any related reports or memos other than the official Progress Reports should be described shortly and attached furthermore as annexes.

For each action (the description of which should start on a new page):

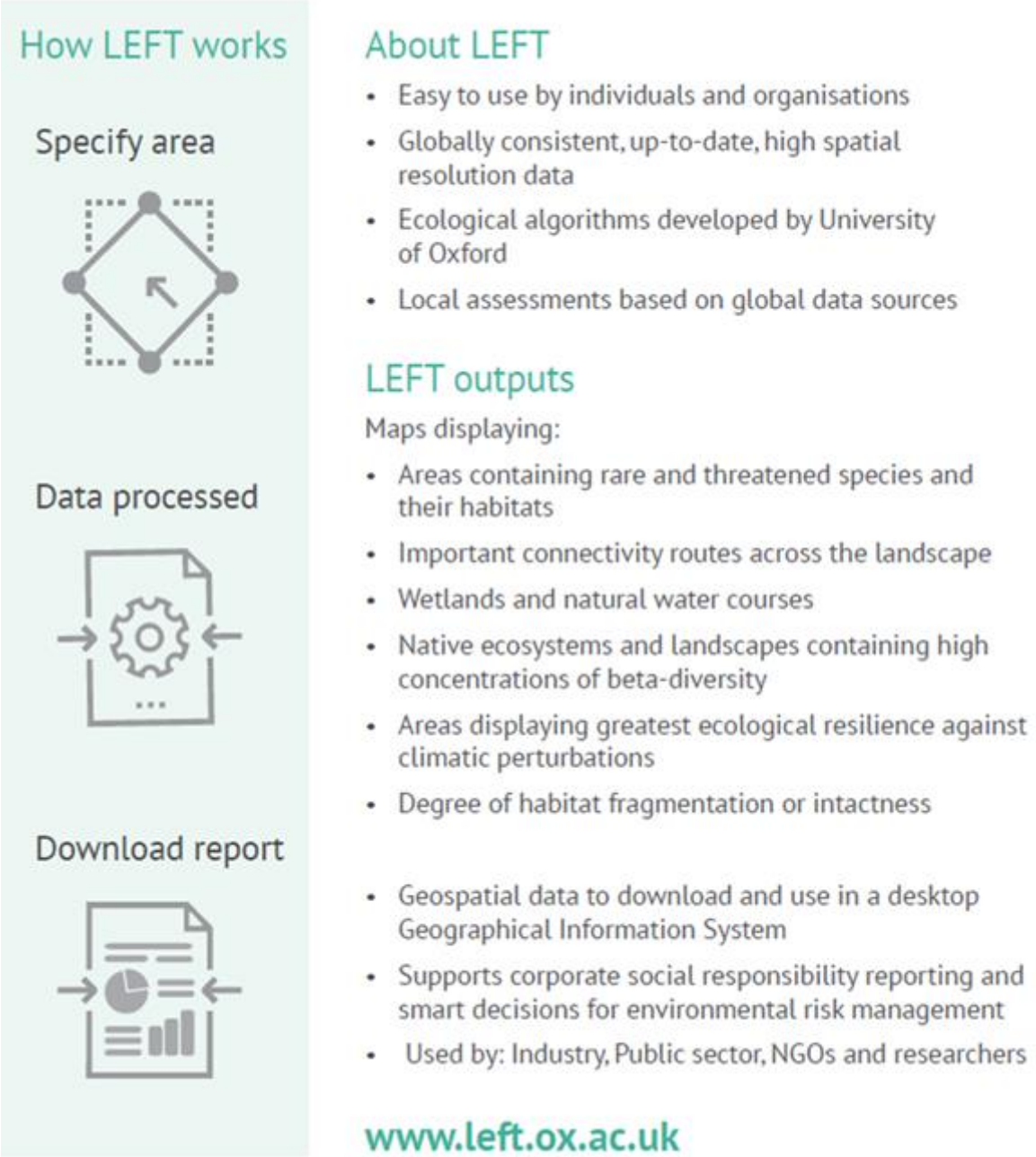
- Describe the activities undertaken and outputs achieved in quantifiable terms (also indicate by whom they were done).
- Compare with planned output and time schedule. (Please note that the overall progress of the project should also be presented using a Gantt-chart or similar – see section 4.1)
- Clearly indicate (when applicable) the indicators used to test the performance of the action.

- If relevant, clearly indicate how actions were modified, and any correspondence with the Commission approving the changes. (In particular this is required if there has been a significant over-spending of the foreseen budget for the action.)
- Clearly indicate major problems / drawbacks encountered, delays, including consequences for other tasks (technical, legal, financial/economic, market, organisational or environment related problems).
- Mention any complementary action outside LIFE;
- Outline the perspectives for continuing the action after the end of the project
- Include tables, photographs etc. to illustrate the actions; for LIFE+ Nature and Biodiversity e.g. land purchase and non-recurring management activities;

5.1.1. Action B1: Development of EcoSET

EcoSET builds upon the Local Ecological Footprinting Tool (LEFT) - (www.left.ox.ac.uk/) - developed by the Biodiversity Institute, Oxford. LEFT is an ecological risk assessment tool that is not only scientifically robust but can be used by non-experts to generate meaningful reports rapidly at appropriate scales for proposed developments that have significant environmental footprints. The outputs from the tool can quickly provide information on (i) areas containing rare and threatened species and their habitats; (ii) important connectivity routes across the landscape; (iii) intact forest landscapes and ecosystem mosaics; (iv) wetlands and natural water courses; (v) native ecosystems and landscapes containing high concentrations of beta-diversity and areas displaying greatest ecological resilience against climatic perturbations. Figure 3 is a schematic overview of LEFT.

Figure 3 LEFT - tool for ecological risk assessment

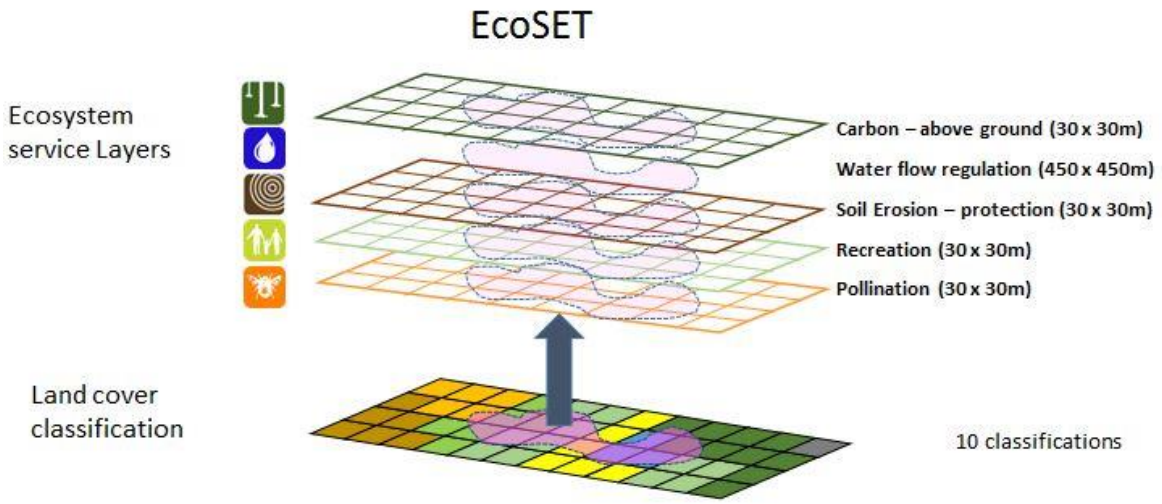


LEFT is being used by a wide variety of stakeholders including the oil and mining industries and environmental consultants because it is easy to use for non-specialists, and provides rapid, repeatable output in an accessible format which has been validated by ground-truthing. LEFT is in the process of being commercialised; the business model will help inform the AfterLife plan of NaturEtrade. User accounts can be set up at www.left.ox.ac.uk. EC desk officers and project monitors can request free credits by emailing leftsupport@zoo.ox.ac.uk .

EcoSET is the 'ecological science' component of NaturEtrade, calculating information for any queried land parcel on the provision of five ecosystem services: pollination, water flow regulation, carbon in above-ground biomass, soil erosion prevention and recreational amenity using complex algorithms, which have been, or are in the process of being, peer-reviewed (a printout of our paper on pollination services is sent with this report). The ecological services are described in more detail below (see 5.1.1. Action B1: Development of EcoSET)

The original delay in some sub-actions of B1, largely caused by a bottleneck in the rate of bulk ordering, bulk downloading and bulk processing of very large numbers of Landsat granules was addressed by using data-reduction methods, sharing the Oxford supercomputing facilities to process satellite data, and contracting Tessella, a SME specializing in custom software development with whom we worked in earlier phases of LEFT to support us in development of code for styled map generation and elements of geoprocessing to calculate summary ecological value, and uncertainty analysis. We have made a minor alteration to the way the project is implemented, not referred to in the Grant Agreement to clarify the position of Tessela Ltd. (https://tessella.com/) , a locally-based international analytics and data science consulting services company, with whom the Biodiversity Institute worked to develop the Local Ecological Footprinting Tool (LEFT). Figure 2 shows how their work was integrated into the project.

Figure 4 EcoSET – ecosystem service data layers



5.1.1.1. Sub Action B1 (1) Data acquisition for ecosystem service layers

Milestone 1 (M1) – started November 2013, due: July 2014. Milestone amended to July 2016. Status: completed July 2016 (but we consider that we must remain on top of new datasets that come on stream as the project progresses and we have amended this sub-action to 'ongoing' so that it remains a point of discussion in meetings and introduced some additional)

We have acquired data for five ecosystem service layers (see Figure 4), developed a pan-Europe tiling scheme (note this extends beyond the EU areas) and prepared ancillary data sets which are needed for ecosystem service evaluation using open access digital elevation models and climate data. We have also established spatial data granule databases and set up dedicated automatic geoprocessing servers within the University- 80Tb space in Aug 2014 and a further 40Tb in 2016 to hold the data which will be required for calculating ecosystem service provision at high spatial resolution.

As time passes, more new environmental data becomes available, such as newly acquired satellite observations required to update the land cover layer. This task will therefore continue until the end of the project and into the afterlife.

5.1.1.2. Sub Action B1 (2) Adaptation of the ecological layers from LEFT

*Milestone 2 – started January 2014, due: December 2014. Amended due: December 2015. Status: completed***.**

It was originally conceived that data layers from LEFT would be presented to users to provide contextual information about the biodiversity value of land parcels which might become subject to transactions for ecosystem service provision. We therefore adapted the procedure which produces these data for LEFT to make the data layers usable within the NaturEtrade web interface. At the workshop in April 2016, stakeholders were presented with these LEFT ecological layers - (i) number of globally threatened terrestrial vertebrate species, (ii) beta-diversity of terrestrial vertebrates and flowering plants, (iii) habitat intactness, (iv) wetland habitat connectivity, (v) number of migratory species, and (vi) vegetation resilience- in addition to the five ecosystem service layers developed for EcoSET as part of NaturEtrade. Users' reaction to this level of complexity confirmed the thinking of the project team that the LEFT layers are not necessary within the market framework of NaturEtrade. It was recognised that they had potential within a policy setting for monitoring and evaluation, but not for trading. LEFT is already being developed as a stand-alone resource stewardship tool, and this was agreed to be the right place for these layers. They are therefore removed from the trading platform that is NaturEtrade, but can be readily re-introduced at a later stage if there is demand. The layers are all compatible. Details of these LEFT layers are outlined in Figure 3.

Tessela was commissioned, in order to streamline our work on B1, to perform map algebra calculations to enable maps to be displayed on the fly in NaturEtrade. This work flowed logically from work they did for LEFT. Their contract is appended (**Error! Reference source not found.**).

5.1.1.3. Sub Action B1 (3) Development of models, algorithms and datasets

Milestone 3 – started January 2014, due: July 2015. Amended due: December 2015. Status: completed.

The models for all five ecosystem services have been developed and are in place in NaturEtrade across the whole of Europe at high spatial resolution using data produced in action B1(1).

Carbon in above-ground biomass

Carbon in aboveground woody vegetation (AGB) has been estimated using a statistical algorithm based on published work by Saatchi et al (2011). We use maximum entropy methods (MaxEnt software package) to apply machine learning to predict distributions of aboveground biomass from a satellite observables such as radar backscatter, moderate resolution spectroradiometer (MODIS) satellite-derived products of vegetation states, landcover maps derived from Landsat data, and other environmental covariates such as digital elevation models. The model is parameterised, and tested for accuracy, using the extensive network of forest plots from US Forest Inventory and Analysis (FIA), has now been applied across the British Isles. Work is now ongoing to extend the model to the rest of Europe.The service of carbon stored in above-ground biomass is the estimated number of tons of carbon / hectare stored in vegetation. Units: tons carbon / hectare.

Soil erosion protection

The algorithm for soil erosion protection uses the Revised Universal Soil Loss Equation (RUSLE) together with land cover, precipitation, and elevation data.

The service of soil erosion protection is defined as the amount of avoided soil erosion from a patch of land as a result of the land cover class (trees, crops, etc) compared to how much soil would be eroded at this location if the land cover were bare soil. Units: tons averted soil erosion / hectare / year.

Recreational amenity

The algorithm for recreational amenity (our chosen example of cultural ecosystem provision) is based on the number of times certain landscapes are photographed and uploaded as social media (Flickr) records, for which specific latitude/longitude co-ordinates have been assigned. We developed a query from the publically available Flickr application programming interface (API) using 729,943 non-urban Flickr records from across Europe. We generated an image distribution model using MaxEnt to relate the occurrence of uploaded photographs to environmental information - landcover class, elevation, 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 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.

At the April 2016 stakeholder Workshop, people queried whether we could use the more popular social media site Instagram, but this cannot be used freely as the AP forbids automated processing of any data without permission of users who have uploaded the images.
The model of the delivery of the service of recreational amenity also takes account of the distribution of human population density and transport infrastructure.
The service of recreational amenity is defined as the area normalised estimated number of people visiting a location per year.
Units: visitors / km2 /year

Pollination
Development of the pollination algorithm is now complete. A manuscript describing pollination services in Europe is in review at the journal Environmental Economics (Nogué et al. 2016). We modelled the distributions of pollinator species in Europe and developed a method to characterize the degree to which a piece of land provides nesting habitats for pollinators which is within flying distance of these species from pollination dependent crops. We are now able to evaluate this algorithm across Europe at high spatial resolution at regular time intervals as the spatial data (action B1.1) becomes available. The model takes account of:

- Land cover class
- Crop dependence on pollination
- Pollinator geographic distributions
- Nesting habitats requirements of pollinators
- Foraging ranges of pollinators

The service of crop pollination is defined as the degree to which a patch of land provides nesting habitat for pollinators within foraging range of pollination dependent crops.
Units: relative pollination units.

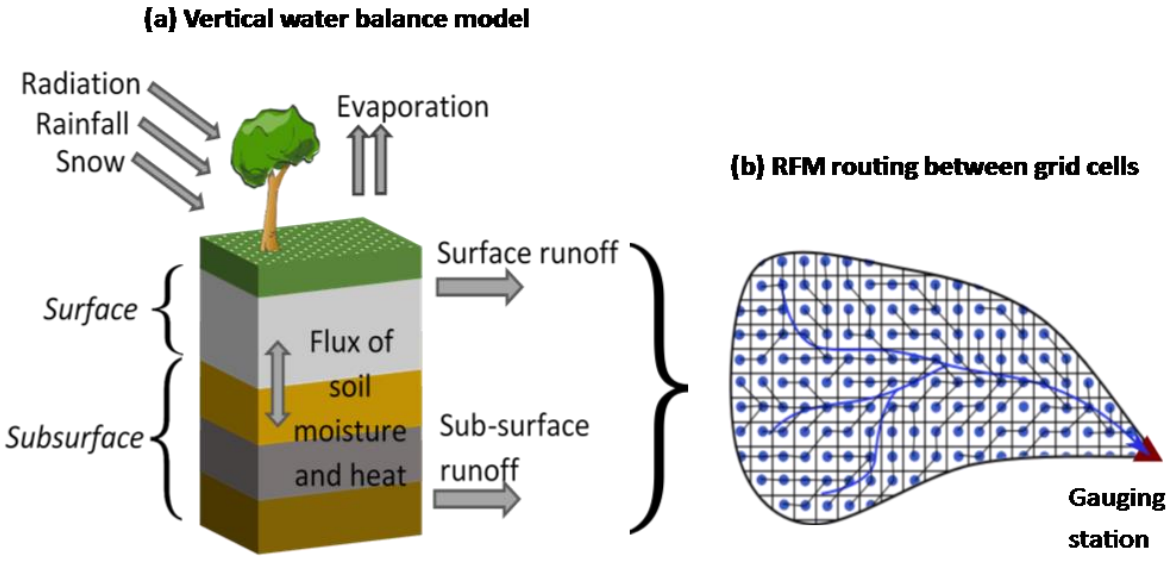
Water flow regulation

A first version on the hydrological layer is now complete for the British Isles, at ~ 450m resolution (15 arc seconds). This map provides a prediction of the volume of rainfall runoff that is prevented by current vegetation cover for each grid cell, through increased evapotranspiration or infiltration into the soil. The model has been tested against measured river flow data for five catchments across England, Scotland and Wales, and the results have been presented at international conferences such as the European Geosciences Union, and to national experts, with positive feedback. Work is now being undertaken to downscale the model output further to 30m resolution, to match the other four ecosystem service layer in NaturEtrade.

The waterflow regulation service has been modelled using the UK regional land surface model called JULES[1], at a finer spatial resolution than ever previously achieved with the model. This physical model uses information about soil type and depth, vegetation cover, slope, precipitation, and position in the landscape to predict the quantity of surface and subsurface runoff generated from rainfall. Runoff is calculated separately for each grid cell across the study area. A routing model is then used to predict the route taken by this runoff across the landscape, to generate synthetic hydrographs of river flow at key locations in the catchment downstream (Figure 5). These hydrographs can be compared against measured river flow data over the same time period to check the accuracy of the model.

[1] https://jules.jchmr.org/

Figure 5 Vertical water balance model in JULES model (a) and horizontal routing of water across the landscape to produce synthetic hydrographs to compare with river flow measurements at gauging stations (b).



Adapted from Dadson et al. [2]

JULES is run twice for the same time period, once with current land cover configurations, and again in a theoretical control scenario with all vegetation removed, leaving only bare soil and urban land cover The difference in runoff generated by each cell at daily time-steps is then calculated, and the mean annual difference presented in the final map.

Figure 6 Figure 5 JULES model is run with two scenarios: control and actual landcover. Runoff is differenced at daily time steps between the two models, and the mean annual difference is presented in the final map as the water flow regulation value

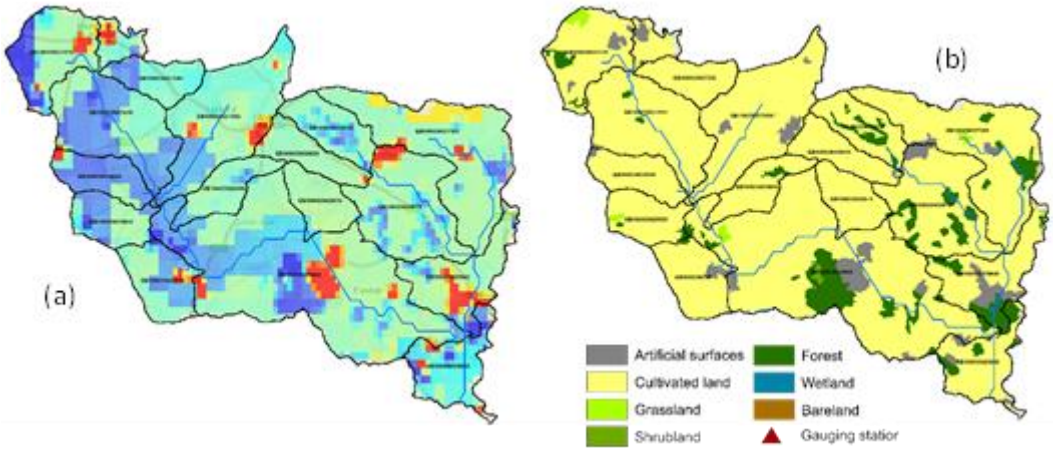
Many factors can affect the quantity of runoff generated in a location, including amount of rainfall, soil type and topography, however the ecosystem service of water flow regulation is concerned only with the role of the biotic environment in this process. By running the model twice under these two scenarios and differencing the results, the effects of soil type, topography, precipitation and meteorology will effectively be held constant, and the result will be a measure of the marginal contribution current vegetation to runoff generation in each grid cell.

<u>Test site results: The Evenlode Catchment</u>

The water flow regulation service map has been trialled in the Evenlode Catchment, upstream of Oxford in the UK. The Catchment is the site of an upcoming Natural Flood Management

project, funded by the Regional Flood Committee, and has suffered consistently from flooding in recent years. The map in Figure 7 shows how current vegetation in the Evenlode catchment affects surface runoff generation. Areas shown in blue are where the current landcover reduces surface runoff the most compared to bare soil. Areas shown in red are areas that behave most like bare soil. The impact of vegetation in clay areas (mainly yellow) is shown as being larger than in limestone areas (pale green-blue) mainly because surface runoff generation in clay areas is larger than in limestone areas where it infiltrates the soil. The model for the Evenlode catchment picks out the few areas of remaining woodland as the most important landscape features for regulating surface runoff and provides broader support for tree planting in clay areas to reduce surface runoff from the catchment.

Figure 7 (a) Water flow regulation in the Evenlode catchment. Red colours show little or no difference in runoff compared with bare soil, dark blue indicates a large reduction in runoff generation compared with bare soil. (b) Landcover in Evenlode catch



The service of water flow regulation is defined as as the maximum amount of runoff from a patch of land with a particular land cover class which was averted because of the land cover. This is calculated by comparing to the amount of runoff which would be produced at this location if the land cover were bare soil.
Units: annual maximum tons water / hectare / hour of runoff averted

5.1.1.4. Sub Action B1 (4) Automation of the Ecoset tool

Milestone 4 – due: Jul 2016; amended to April 2017. Status: ongoing.
We have produced five ecosystem service layers based on British land cover in the year 2010, which was derived from the Globeland30 data set. These layers serve as demonstration data, proving that we can apply theoretical algorithms to real-world data and generate meaningful measures of ecosystem services. The demonstration layers have also been useful visualisation aids for developing and exhibiting the Naturetrade website.
Each layer required at least two months to produce. This time included the acquisition of raw data, writing code to transform the data, processing, and post-processing to put the layer in a format suitable for display online.
Our next step is to produce land cover from satellite-observed reflectance for Europe in the year 2016. That land cover will feed into the algorithms used previously, yielding 2016 ecosystem service layers. We have downloaded reflectance imagery for most of 2016. Work

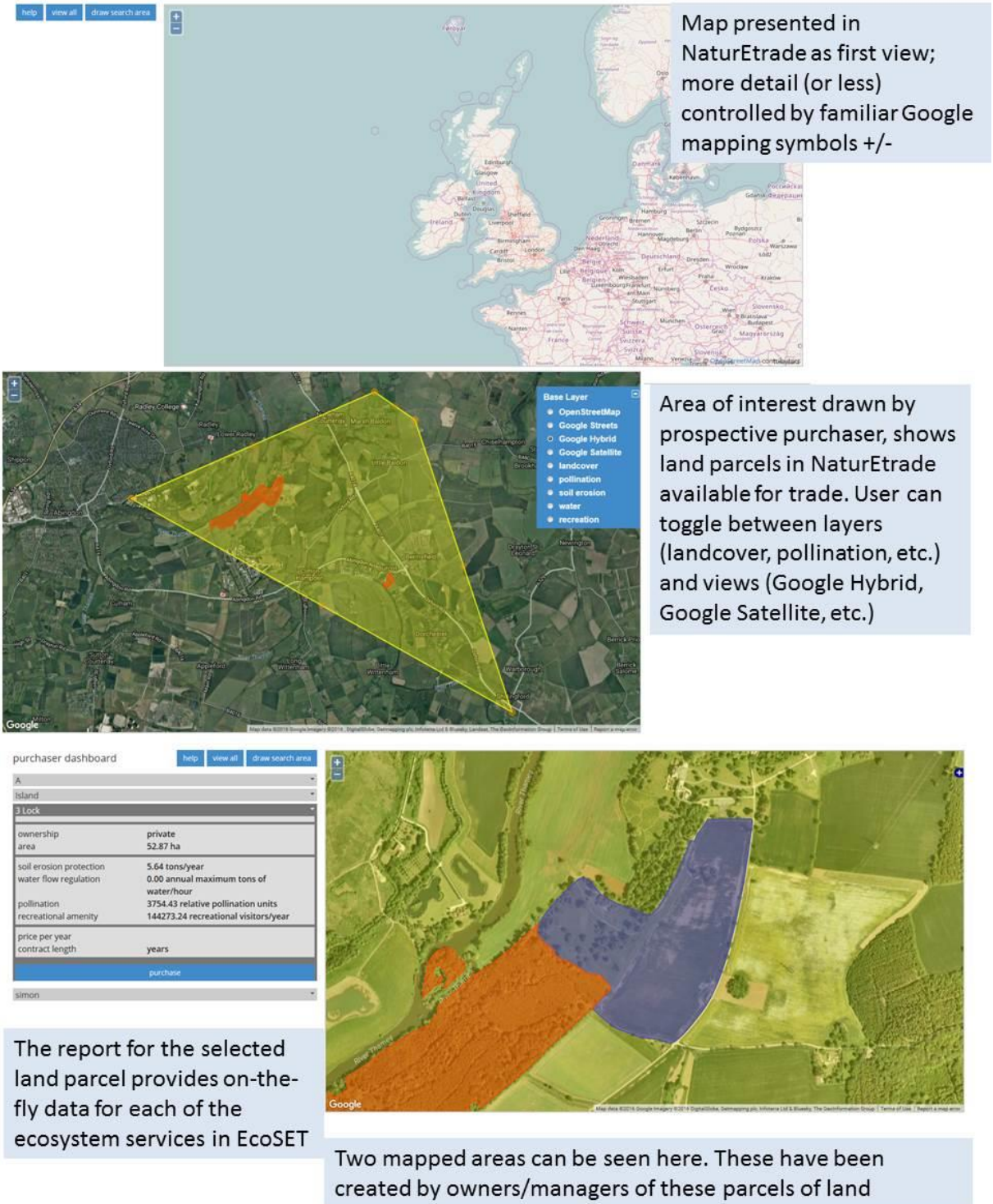
in the next quarter will focus on downloading the remaining data for this year, testing and applying our code to identify land cover from reflectance, and running the ecosystem service processes with the new land cover input.
We will take advantage of the supercomputing clusters at the University of Oxford's Advanced Research Computing facility to process these large data volumes most rapidly. Some effort will be devoted to altering our local ecosystem service code so that it can run in a supercomputing environment. Once we have succeeded we will work on packaging the code for each layer in a script that can be run on a scheduler, producing ecosystem service data every three months with minimal intervention.

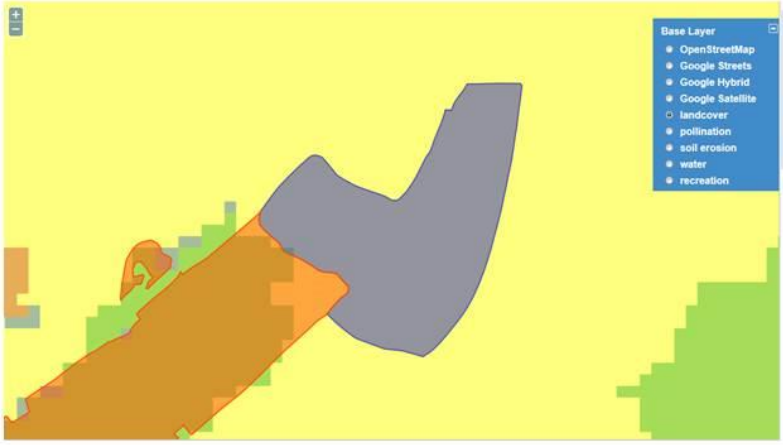
5.1.1.5. Sub Action B1 (5) Completion of Ecoset

Deliverable 1 – due: Jul 2016. Status: completed for demonstration purposes; major update due: April 2017.
Land cover, all ecological layers and all ecosystem service layers have been calculated and integrated into the NaturETrade web interface so that they can be viewed by users. The following images are taken from the NaturEtrade website showing the report detailing values for each ecosystem service for a particular land parcel.

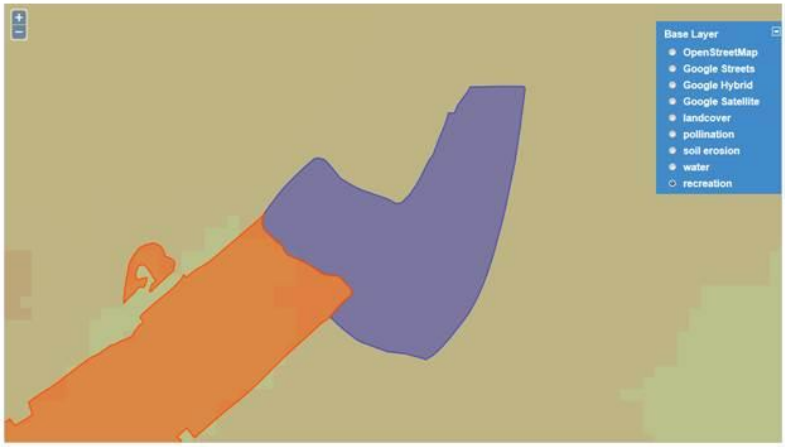
There is no practical way by hardcopy report to deliver evidence of completion to the EC (apart from inviting officers to create a free account and logging onto NaturEtrade), however, it was demonstrated to the EC at the joint mission on 22nd November 2016. The system was tested extensively during the April stakeholder workshop. The current working model of NaturEtrade uses landcover data from a Chinese 2012 data set; this is accurate enough for demonstration purposes in our workshops, but will be replaced in March/April 2017 by more recent data. One of the key tasks of the person(s) responsible for technical aspects of NaturEtrade after the project finishes in 2018 will be updating, as appropriate, the landcover and ecosystem services data layers as improved data becomes available on the internet for free use (**Error! Reference source not found.**.)

Figure 8 EcoSET layers as they appear to buyers and sellers in NaturEtrade





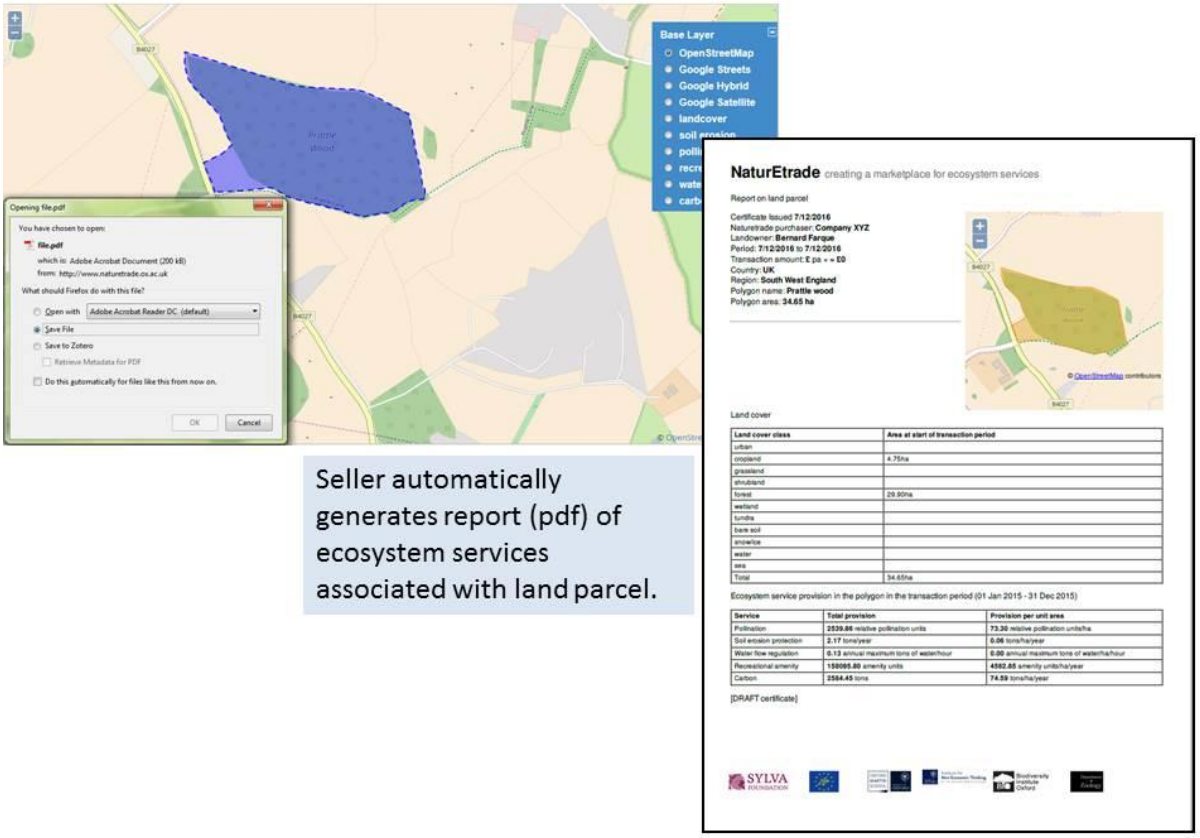
Toggling landcover layer to see mapped area and landcover in surrounding areas



Toggling recreation layer to see mapped area and provision of recreation in the mapped area and surrounding areas

Area of interest automatically identified from land registry data by prospective seller (owner/manager of land parcel), shows Prattle wood Seller can toggle between layers views (Open StreetMap, Google Satellite, etc.)

Owner can toggle between layers views (recreation, carbon, etc.) to examine relative value of the land parcel compared with surrounding areas.



4.1.1.6. Sub Action B1 (6) Report detailing the design of Ecoset

Deliverable D2 – due: July 2016. Status: completed; delivered with the Mid-term Report
See **Error! Reference source not found.** (also attached as a print-out with this report)

4.1.2. Action B2: Creation of NaturEtrade

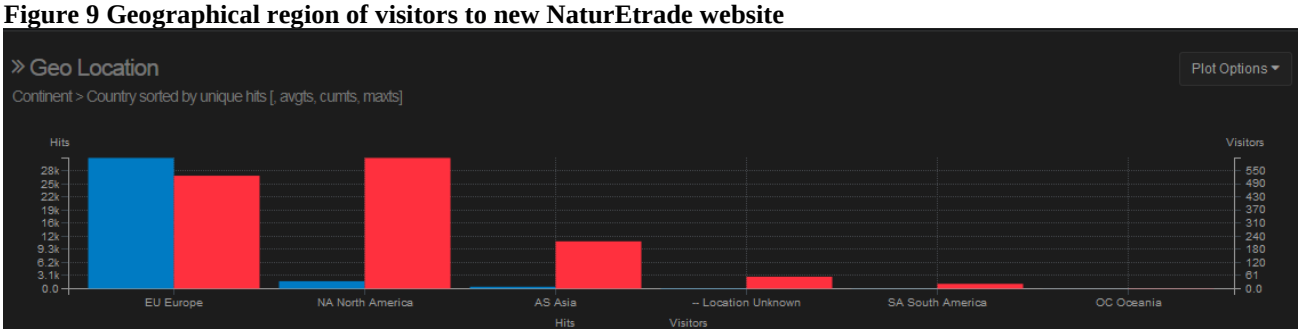
The NaturEtrade web interface provides a platform for marketing and trading ecosystem services. It allows landowners access to detailed information about ecologically important features of their land and ecosystems service provision on their land. Potential buyers of ecosystem services can search the set of land parcels which landowners are offering and establish contracts to pay landowners to maintain ecosystem service provision by preventing undesirable land cover change. As of July 2016, we cannot verify land cover change over time (see B3(5) below) and cannot therefore conduct real transactions, but the architecture exists within the platform to establish and maintain contract linkages between sellers and buyers. Our stakeholder workshop for buyers will be conducted in collaboration with the Surrey [UK] Wildlife Trusts and Surrey Nature Partnership (in February 2017 and at this point, real transactions will be tested for contracts lasting 12 months (i.e. finishing Feb 2018, in the quarter before the project ends).

Sub Action B2 (1) Design and set-up of NaturEtrade website

Deliverable D3 – Completed; delivered with the Inception Report

Project website was set up in April 2014. It was substantially updated and merged with the NaturEtrade platform in May 2016 following stakeholder feedback (see B2(7) below). We will track web usage on the new website systematically from 2017 and will monitor the success of our dissemination activities. Very preliminary statistics, however, do represent a range of countries and regions (Figure 1). These figures will be more useful once we increase publicity outside stakeholder meetings and run workshops in the three other EU countries.

Figure 9 Geographical region of visitors to new NaturEtrade website



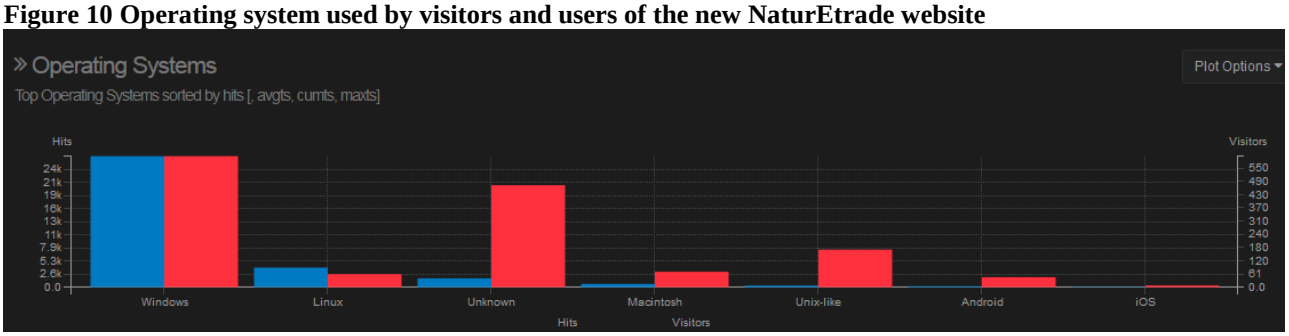
Sub Action B2 (2) Development of mobile data capture device

Deliverable 4 Completed; delivered with the Inception Report.

The platform is fully functional on mobile devices and was tested on tablets and mobile phones during the April 2016 stakeholder workshop. Land parcels can be uploaded and searched, ecosystem services reports read and downloaded, and theoretically, payments made (see B3(5) below for explanation of current status of transacting in NaturETrade).

We have tracked a small number of users who are accessing NaturEtrade on mobile devices (Figure 10) and we expect this number to grow.

Figure 10 Operating system used by visitors and users of the new NaturEtrade website

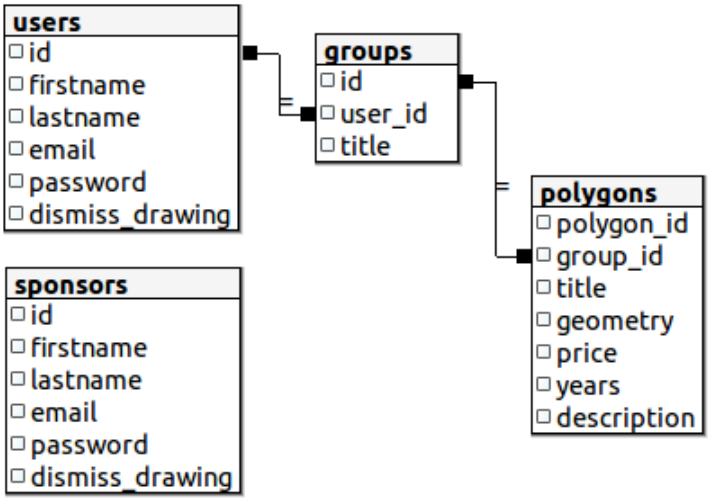


Sub Action B2 (3) Development of NaturEtrade database structure

Milestone 6 Completed; delivered with Mid-term Report.

Figure 11 shows the logical framework linking users and the mapping details they provide in NaturEtrade.

Figure 11 Schema of the NaturEtrade users and polygons database

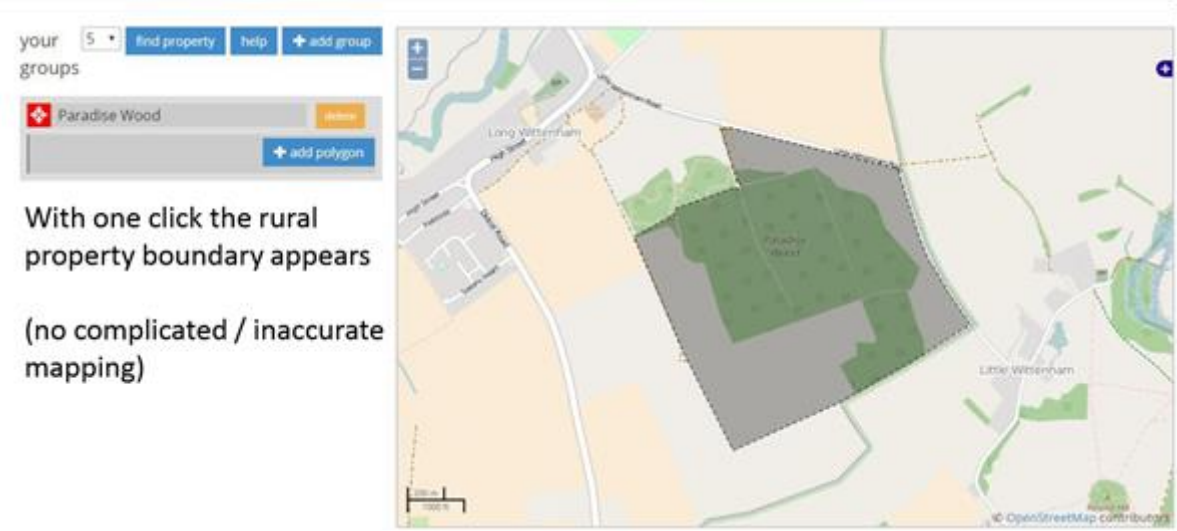


An important breakthrough followed several discussions with the UK Land Registry and a meeting in Oxford at which we demonstrated NaturEtrade: they agreed to provide us with bulk INSPIRE Index Polygons of registered freehold land and property in England and Wales.

We have incorporated these official Land Registry polygons for England and Wales into the NaturEtrade map interface, and these can be automatically selected by users, instead of manually drawing a land polygon using the map interface. We will download those for Scotland in due course.

Figure 11 shows how the system looks in NaturEtrade, with the grey area representing the Land Registry polygon. We have been advised that there will be challenges in implementing similar arrangements in our three other countries, owing to a less advanced state of compliance with the INSPIRE directive. We have retained a manual mapping option, which can be used easily, and will be essential in our other EU countries which may not have, or be willing to share with us, their land registry polygons or other data.

Figure 12 Land Registry polygons integrated into NaturEtrade for accurate mapping of properties to trade



Sub Action B2 (4) Linking EcoSET and NaturEtrade

Milestone 7 - due: April 2016. Status completed; delivered with Mid-term Report

We have implemented a procedure to converted geotiff tiles into tiled-map-service (TMS) compatible folder structures of PNG images, with a custom palette applied and a legend, using the open-source GDAL software library. Users can pan and zoom the slippy map and toggle between viewing different layers and base data. We have also implemented on-the-fly zonal statistic calculations for the five ecosystem service data layers within user-generated polygons representing land parcels. This is accomplished by processing the tiled geotiff environmental data on-the-fly using the PostGIS library. The zonal statistic calculations are performed on the webserver on each of the polygons stored in a PostgreSQL database as soon as they are written to the database by making a call to PostGIS. A java function is used to poll the database and pass a command to PostGIS and then write the zonal statistics results into the database.

Figure 8 shows how buyers and sellers see the results of these behind-the-scenes calculations performed on parcels of land drawn from Land Registry data or hand-drawn. The report showing values for each of the ecosystem services is almost instantaneous because the servers store the raw layer data and these are not interrogated from the web each time a calculation is performed.

The values for each layer have been chosen to be scientifically meaningful and also simple enough to be clearly understood by our stakeholders (Table 2).

Table 2 – Ecosystem services in NaturEtrade: definitions and values

Ecosystem service	What the service indicates	Value
Pollination	The service of crop pollination is defined as the degree to which a patch of land provides nesting habitat for pollinators within foraging range of pollination dependent crops.	relative pollination units
Soil erosion	The service of soil erosion protection is defined as the amount of avoided soil erosion from a patch of land as a result of the land cover class (trees, crops, etc.) compared to how much soil would be eroded at this location if the land cover were bare soil.	tons averted soil erosion/ hectare/year
Water regulation	The service of water flow regulation is defined as as the maximum amount of runoff from a patch of land with a particular land cover class which was averted because of the land cover.	annual maximum tons water/ hectare/hour of runoff averted
Carbon	The service of carbon stored in above-ground biomass is the estimated number of tons of carbon in each hectare stored in vegetation.	tons carbon/hectare
Recreation	The service of recreational amenity is defined as the area normalised estimated number of people visiting a location per year.	visitors/km2/year

(Projects submitting final reports after 1 January 2014 must use this format.)

Sub Action B2 (5) Interface system linking sellers & buyers

Milestone 8- due April 2016; completed, demonstrated in theory at workshops, but not yet live-tested.

The database structure has been developed to make this possible once we test simulated-live linkage. The theory has been well researched and presented to stakeholders at the April 2016 workshop. What's important in a good market

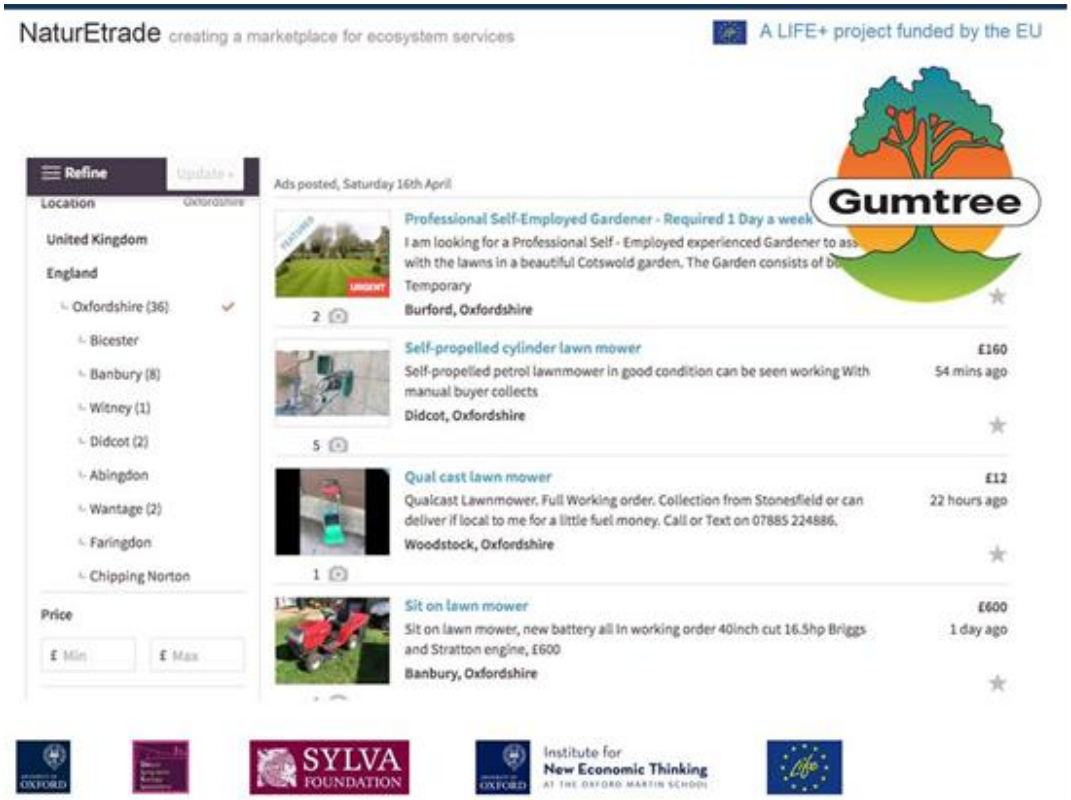
- Find the best transactions out here
- Low transaction costs
- Transactions happen quickly
- Participating is easy and safe
- Participants return to transact again

We have taken an iterative approach to developing this linkage, going from simplest to more complex user matching.

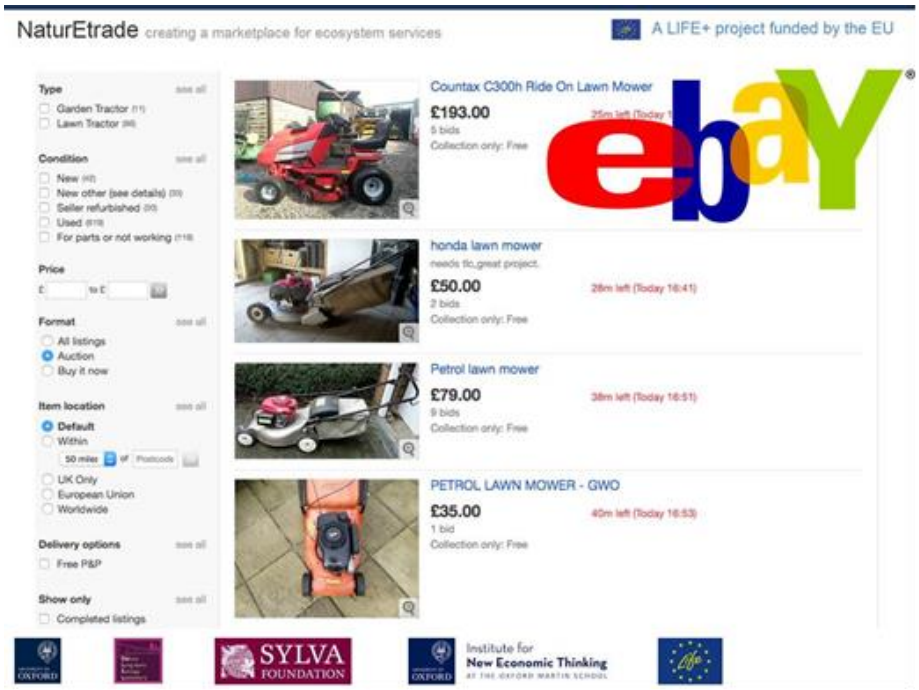
The market options we have identified are, in order of increasing technical complexity (and market optimisation):

1. Gumtree model
2. eBay model
3. Spectrum auction

1. Gumtree model – all properties shown with their trading values (example here shows lawnmowers; NaturEtrade would show parcels of land with ecosystem services values and landowner's asking price). Sales are immediate.



2. eBay model – again showing lawnmowers (=land parcels in NaturEtrade). Sales follow a period of ‘auction’, the length of which is decided by the seller,at the end of which the highest bidder gains the item.



3. Spectrum auction – in this example London bus routes are auctioned in bundles of routes starting and finishing from common nodes, to maximise efficiency for the bus companies. Bids are received and auctions held on pre-determined, specified dates.

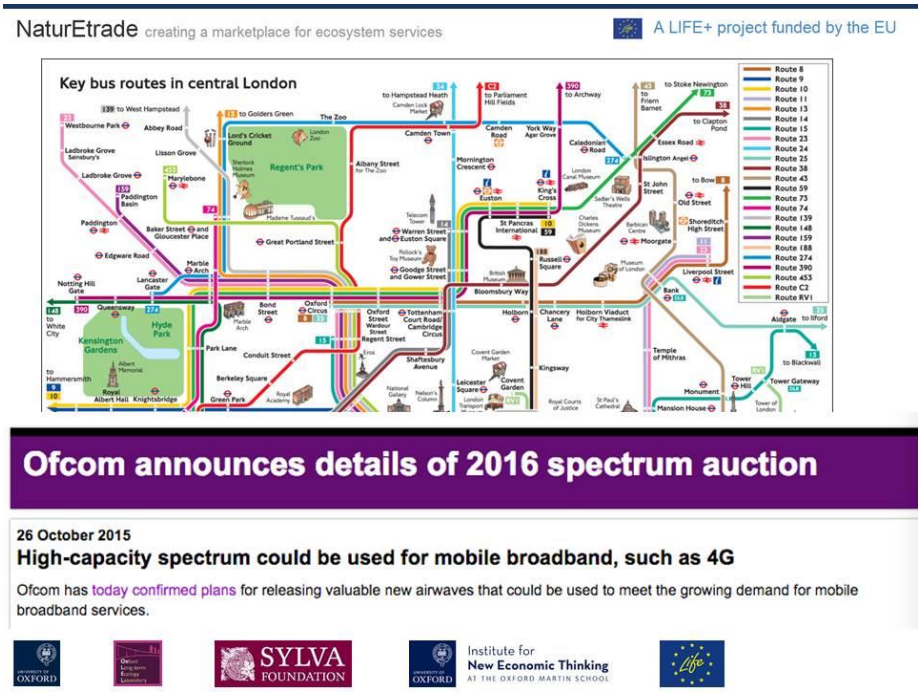


Table 3 Summarises benefits and drawbacks of each model. **Error! Reference source not found.** shows how the models behave for buyers and sellers with different scenarios.

Model	Benefits	Drawbacks
Gumtree	Transactions are immediate; Complete certainty for buyers & sellers.	Landowners might set offer price too high; Buyers who bid *early* potentially get a bargain; Landowners do not get highest possible price.
eBay	Landowners get a much better deal; They can honestly set a reserve price; Buyers can bid honestly; More successful transactions.	Transactions are not immediate; Buyers who want more than one plot *together* can be thwarted when one plot is sold before they have finished bidding.
Spectrum auction	Landowners get the best possible deal; Buyers can enter into contracts with many landowners simultaneously; Landowners can honestly set a reserve price; Buyers can bid honestly.	Auction runs and ends for everyone at the same time.

Table 3 Market models for NaturEtrade: advantages and disadvantages

Sub Action B2 (6) Pilot tests of NaturEtrade

Milestone M9 – due: July 2016, Status - Completed for UK; ongoing for Spain, Romania, Croatia

We have been piloting developments of NaturEtrade with interested parties who, attended our two stakeholder/knowledge exchange workshops and used feedback from them to guide our work. The April 2016 workshop included people who made firmer commitments to work with us and these collaborations will continue throughout the rest of the project (see collaborating organisations, in column 2 of **Error! Reference source not found.**)(see XXXX below for detailed discussion). We have delayed piloting the project in Spain, Romania and Croatia until we have reached a secure stage of development within the UK. We will begin working in non-UK countries in 2017.

Sub Action B2 (7) Modifications to NaturEtrade after feedback

Additional milestone added xMi: due ongoing from July 2015

We added this as a milestone to review following each stakeholder workshop or meeting to ensure that we kept track of suggestions that arose from people testing the system at workshops or in other live demonstrations. The most significant alteration to date has been to merge the trading platform with the project website so that ultimately all the information on the project will be in the same place as the functionality for using the tool.

4.1.3. Action B3: Standard contracts/verification tool

Sub Action B3 (1) Review of existing contracts for ecosystem services

Milestone 10 completed; delivered with Inception report, and appended here (**Error! Reference source not found.**)

Sub Action B3 (2) Governance arrangements devised

Milestone added as M10c: due December 2015; status- Completed to working draft, but to be revised following stakeholder feedback after workshops as necessary.
Annex 5 details the governance arrangements devised to date and tested with stakeholders in the UK at two workshops. We will continue to improve these governance arrangements following stakeholder feedback in all four countries.

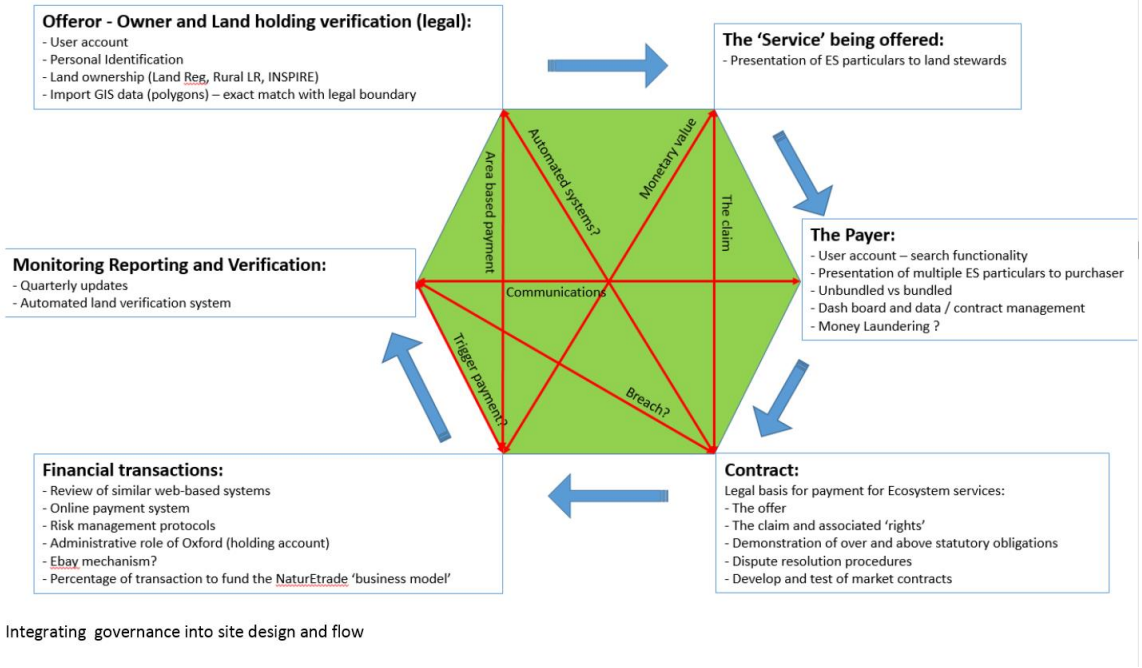
Sub Action B3 (3) Develop and market testing of pilot contracts

Deliverable D5: due Dec 2015; status: partially completed
Contracts have been developed and tested in two UK workshops. Further testing with buyers and sellers in Surrey, UK will take place in Feb 2017.

Sub Action B3 (4) Contracts integrated into NaturETrade

Milestone 11/Deliverable 5 –Due July 2015. Amended end date: December 2015
A working contract has been devised and tested with stakeholders (April 2016 workshop). It is considered robust enough to be used for the purposes of demonstrating NaturEtrade, however. It has been reviewed by University of Oxford legal services and we are developing in discussion with them before implementing a fully-operational payment system. The payment system we use for LEFT has been fully signed off by our legal advisors, and we will follow as closely as possible this model for NaturEtrade. It will also need to be reviewed in our other three countries.
Figure 13 shows how we are integrating the contracts and other governance considerations into NaturEtrade. Note that payments are only made to landowners after verification, although money from buyers is collected and stored securely by the University of Oxford at the point of making the contract (see Figure 14)

Figure 13 Integrating contracts and governance considerations into the design of NaturEtrade



Sub Action B3 (5) Automated land verification system developed

Deliverable D6 due: July 2016. Status: ongoing.

In this action we are developing a system for comparing land cover maps at two time points in order to be able to determine whether unacceptable land cover changes have occurred on a parcel of land subject to a NaturEtrade contract over a particular period of time.

The land verification tool uses a time series of land cover maps, which will be produced automatically for the whole of Europe on a rolling basis. The spectral classification procedure identifies 10 different land cover classes (labelled 0-9). For each annual time interval, the land cover maps from times t1 and t2 will be combined to make a map of change classes during that time interval. This will be accomplished by multiplying the t1 class digital numbers (0-9) by 10 (to yield 0-90) and adding to the t2 digital numbers (0-9). The result will be a map of 100 change classes (0-99). We will then zonally query the map of delta (change) classes for each time interval by every land polygon in the NaturEtrade database such that we know the frequency of every change class in every land polygon. This is accomplished using zonal statistics functionality developed in action B2 (4).

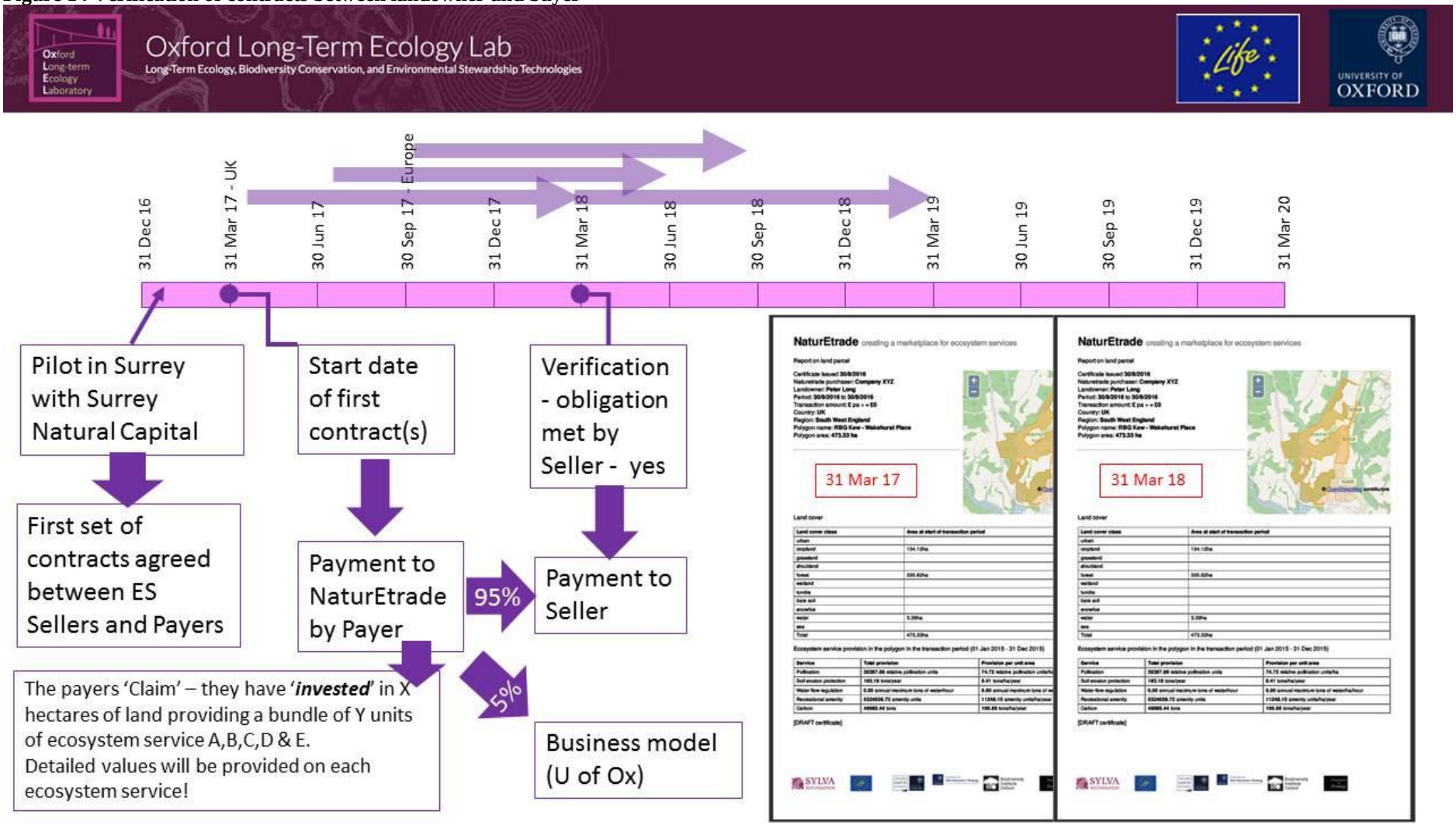
In an ideal scenario, over a time interval, all pixel transitions will be on the diagonal of the transition matrix (i.e. transition from a class at t1 to the same class at t2). However we have to take account of the fact that the classification procedure is not perfectly accurate. Users' accuracies of the order of 0.95 are to be expected for a single date classification, and therefore users accuracies of the order of 0.95^2 =0.90 are to be expected for delta classes. However users' accuracies will likely differ between classes and classification errors will likely be correlated in time, so we will need to conduct a validation, probably using high spatial resolution images such as are available in Google Earth.

We will then develop a decision rule which can be applied automatically in the NaturEtrade database to determine whether or not any significant land cover change has occurred on a land polygon during a transaction period, taking account of the expected error in the delta classification procedure.

Figure 14 shows conceptually how the contract will be invoked and completed. Note that payment to the landowner will only occur after verification, i.e. 12 months after the contract with the buyer. This is an important consideration in our design of NaturEtrade. Money will be taken from the buyer and held securely in an account administered by the University of Oxford, which will exact a small administration fee (5%), and pay the residuum after verification (12 months).

(Projects submitting final reports after 1 January 2014 must use this format.)

Figure 14 Verification of contracts between landowner and buyer



(Projects submitting final reports after 1 January 2014 must use this format.)

Sub Action B3 (6) Database linkage between NaturEtrade and land verification system

Deliverable D7, due: July 2016. Status: completed and demonstrated to the EC Mission of November 2016.

This action has been accomplished in the same way as task 2 of action B2.4. Once M7 of B2.4 was reached in Apr 2016, completion of action B3.6 followed, as the same code was be used to link the periodic results from the land verification system to the PostgreSQL database holding the land parcel polygons and hence into the NaturETrade web interface. This action depended on completion of action B3.5 deliverable D6 in Jul 2016; action B3.6 deliverable D7 was completed in Jul 2016.
The screen shots of the system in action, provide some indication that the Action is complete; however, it is best seen through logging on and using NaturEtrade. It was demonstrated live to the EC joint mission in November 2016.

4.1.4. Action C1: Monitoring of impact of EcoSET & NaturEtrade

Action C1 (1) Rates of land cover change determined
Milestone 13 – due: July 2015. Status: Ongoing
To establish historic rates of change between landcover classes, we will download satellite observables and perform a landcover classification for the years 2001, 2006, and 2011, using the same methodology as the ongoing classification we will use to establish landcover changes in B1 (see 5.1.1. Action B1: Development of EcoSET). We will then calculate the rates of conversion from 'biodiverse' land cover classes (i.e. grassland, shrubland, forest, and wetland) into other classes. Results will be categorised by sub-national administrative regions across Europe. This will allow us to identify areas of high loss, where biodiversity is at greatest risk. The trends will also be used to model a counterfactual scenario, showing how landcover might continue to change in the absence of NaturEtrade. By focusing on similar landscapes near NaturETrade sites, we will be able to assess the project's effectiveness.

Although in the Grant Agreement description of this action we referred to the Corine landcover classification (CLC) for measuring change, we have decided that an in-house classification will ensure greater consistency and more reliable rates of change.

Action C1 (2) Regions for workshops selected

Milestone 14 – due: July 2015. Amended Dec 2015. Status: Completed for UK, Romania, Spain; Ongoing for Croatia
We have run exploratory workshops in the UK in Oxfordshire and selected Surrey, UK, Mures, Romania, and Catalunya, Spain as regions to hold workshops of buyers and sellers interacting with the refined version of the platform (Figure 15). We are still in discussion with Croatian colleagues to select an appropriate region for a workshop there. We had envisaged that the regions selected for workshops would be administrative regions with the greatest rate of loss of 'biodiverse' land cover classes. However, experience with the UK workshops is that the success of the workshops will have very little connection with biodiversity loss but will be entirely dependent on getting representative groups of people willing to test and discuss the project within the context of their own experiences. We are therefore working with people who originally

expressed willingness to help participate in and facilitate the workshops to suggest venues and participants.

Figure 15 Regions for NaturEtrade workshops

Action C1 (3) Workshops run in selected regions for landowners

New deliverable XDiii – due July 2015; amended July 2017
Two preliminary workshops have been held in the UK in Oxfordshire to demonstrate the potential for NaturEtrade using interim landcover data (see 5.1.1.1. Sub Action B1 (1) Data acquisition for ecosystem service layers). Detials of the two UK workshops are on the website, together with photographs of the events (http://www.naturetrade.ox.ac.uk/news)

The working version of the landcover layer will be available for use for the third UK workshop, for both landowners and businesses in Surrey, UK in early 2017. Workshops in Spain, Romania and Croatia will follow later in 2017.

Action C1 (4) Report on Workshops

Deliverable D8 – due Oct 2016, amended Oct 2017
Reports of the UK workshop will be delivered to the EC with the second Progress Report; reports of workshops in the other three countries will be submitted with the Final Report.

5.2 Dissemination actions

5.2.1 Objectives

Stakeholders involved and main target audience of the project

We have been developing a database of individuals and organisations who have contacted us about NaturEtrade and LEFT. **Error! Reference source not found.** shows only names of the organisations (multiple individuals from some organisations have been involved in workshops and meetings). The second column shows those organisations who have helped shape and develop NaturEtrade to date. The complete database holds personal information, such as email and notes of discussions and action points. These are held securely on University servers. The databases of the Sylva Foundation are available for NaturEtrade but not copied, for data protection reasons, to the University servers.

Our dissemination actions up to the mid point have targeted mainly land owners and managers. These are likely to be overwhelmingly ‘sellers’ in NaturEtrade. However, we have envisaged stakeholders as comprising three broad groups: sellers and buyers of ecosystem services identified and offered through the site, and also those who use the information contained in the ecosystem accounting framework and quantification of ecosystem value on land parcels to contribute to their own conservation programmes and objectives (who could also be buyers and sellers involved in trading in the site).

1. Sellers:
Our primary target group are the private forest owners, who we assign to one of three groups, depending on their potential willingness/ability to engage with NaturEtrade, which will affect our strategy for engaging them:
a) Business-oriented forest owners, who tend to own larger tracts of land (at least tens of ha). They may want to generate profits from the point of ownership, or may have a long-term profit perspective and understand the need for sustainable forest management. Whichever is

the case, if their contribution to nature conservation affects profitability, they expect compensation;
b) Owners who manage their forests for household and farm needs (firewood and timber), whose holdings are usually small. They have neither sufficient yield nor interest to enter the timber market, so profitability is not their primary consideration. These owners cut trees selectively according to their needs. As long as these needs are satisfied, they can accept nature conservation measures. However, they may be forced by their own financial situation to clear-cut their forest;
c) Forest owners whose connection to their property is weak. They often live away from their forest, usually in cities. They do not expect profits from their property, and if they do, they tend to sell it (then it is often logged). This group is open to conservation values – they often appreciate the landscape and ecological role of their forests. We will engage with these sellers in the first instance through key land-owner organisations, including the European Forest Owners (CEPF), which is the umbrella association of national forest owner organisations in the European Union (http://www.cepf-eu.org/index.cfm), the European Landowners' Organisation, (http://www.europeanlandowners.org/) and the Country Land & Business Association (http://www.cla.org.uk/).

2. Buyers:
One important source of buyers will be through the marketplace for Corporate Social Responsibility (CSR) actions. We had envisaged working first through companies who are already engaged in CSR activities via Business in the Community (BITC) in the UK, a business-led charity with a membership of 850 companies, from large multinational household names to small local businesses and public sector organisations (http://www.bitc.org.uk/). Their environment programme fits well with our aims in NaturEtrade:

> "*Our purpose is to inspire action leadership that turns environmental challenges into opportunities for new jobs and skills, builds resilience into key value chains and leverages systemic change that multiplies the positive impacts business can have.*" (Business in the Community, Annual Report, 2016).

For our other three EU countries, we will work via CSR Europe (http://www.csreurope.org/), which is the leading European business network for CSR with around 70 multinational corporations and 29 national partner organisations as members in 24 European countries.

Following the second of our two preliminary UK workshops in Oxfordshire, we were approached by Surrey Wildlife Trust to use NaturEtrade as part of the strategy for income generation for land owned and managed by Surrey county in public trust. In early 2017 we will hold a workshop for businesses and land managers in Surrey at which working contracts through NaturEtrade will be agreed.

Our UK workshops and follow-up meetings with various organisations has confirmed our belief, set out in the Grant Agreement, that in the longer term, NaturEtrade project can contribute significantly to ecosystem system service mapping and assessment throughout the EU, separately from any trading activity. We anticipate that it will serve as a model for application elsewhere in the world. We have promoted the project at meetings with the UK's Department for Environment, Food and Rural Affairs (Defra) and two water companies

(Thames Water, and Anglian Water) and have given presentations of NaturEtrade at international meetings, where the project has generated much interest.

What appears to be most compelling for these potential stakeholders is the mapping of ecosystem values at the level of individual properties, which can clearly provide a baseline and measure of change across time which will enable many organisations who engage in conservation or restoration activities to quantifiably assess the impact of their work at the ecosystem level. Users of the data are therefore likely to come from the NGO sector, protected area managers, public sector conservation authorities looking for quantifiable measures of programme effectiveness and value for money, and private sector foundations looking for an extra layer of information on their existing or potential conservation investments. By measuring what before went unmeasured and undervalued, simply providing robust quantitative ecosystem service measures will significantly contribute to conservation outcomes and catalyse new investment in conservation and restoration activities.

(Projects submitting final reports after 1 January 2014 must use this format.)

5.3 Evaluation of Project Implementation

Table 4 Evaluation of project implementation

Task	Foreseen in the revised proposal	Achieved	Evaluation
Establish spatial data granule databases, set up automatic geoprocessing servers	Yes	Yes	Additional servers purchased to speed up work, overcoming an earlier bottleneck which was holding up other work
Acquire data for ecosystem service layers and develop tiling scheme for Europe	Yes	Yes	We started with less well-known layers - pollination and recreation largely to excite people in the innovative nature of our project. The approach worked well. Water required more work than we had anticipated, but linked us in with others using JULES and has led to the richest collaboration so far, which we view as a major benefit to the project. Carbon, possibly the most contentious layer, as it is conflated with work in the wider forestry community on carbon calculations for initiatives such as REDD (Reduced Emissions from Deforestation & Degradation), and with work done for setting carbon prices in a market, neither of which are central to our project.
Prepare ancillary data sets across Europe which are needed for ecosystem service evaluation including digital elevation models and climate data	Yes	Yes	Work on LEFT fed directly into work on this task, providing at least 18 months' saving in intellectual and model development time.

Adapt ecological layers from LEFT for incorporation into EcoSET	Yes	Yes	Feedback from early users and our own views about the desirability of having LEFT layers inside NaturEtrade led to us keeping them out of the tool. The layers are not ecosystem services and they are better suited to a one-time evaluation of land than continuous monitoring. This decision can be reversed relatively easily however should the views of stakeholders and/or the market change. The two tools are always demonstrated separately at meetings, conferences, etc.

Develop and code the algorithms which use land cover and ancillary data to estimate ecosystem service provision	Yes	Yes	We have developed a method to remotely estimate the distribution and type of vegetation cover using freely available data sources. To develop a global landcover classification map at 30m pixel resolution, we therefore obtained satellite data from the NASA Earth Information system. We downloaded images from both the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument and Landsat 5,7,8 from years 2000-present. We then combined these to create a high spatial resolution estimate of seasonal surface reflectance and temperature at 3-monthly intervals We spent some time developing a spectral classification tree procedure (following Baraldi 2006) to covert these data to a land cover classification at 30m resolution. The Baraldi method proved unequal to our task, however, and we adapted our thinking to overcome the problems. The approach will be outlined in a paper in 2017. We had originally planned to use Corine Land Cover 2006 data which has a spatial resolution of 100m, with minimum size of mappable features being 25 ha. Despite this being one of the most high resolution land cover maps, it is insufficient for the accurate representation of some of the fine distinctions in ecological and ecosystem service features, and does not take into account smaller features, such as small patches and hedgerows, which have been shown to be important in supporting ecosystem services within the landscape. It became obvious early in the project that this would not provide the sort of granularity needed to assess ecosystem services on the types of land parcels we were hoping to attract into NaturEtrade. The change to 30m resolution has taken a lot of additional modelling and processing time, which has delayed full delivery of this task. However, the result is a much better tool. We are using placeholder landcover data from a Chinese source for 2012, but this will be replaced in late 2016/early 2017 with data that we can use to perform quarterly evaluations of landcover.

Automation of the EcoSET tool	Yes	Yes	Having overcome problems and delays in the task above, this was a relatively rapid and problem-free task
Test integration between system components and validate the final aggregated ecosystem service provision outputs.	Yes	Yes - in theory	Validation in practice will be achieved in 2017 (see issue above with the placeholder landcover data that is currently drawn into NaturEtrade for demonstration purposes
Design and setup of NaturEtrade website	Yes	Yes	Completed one major update of the site to incorporate the trading platform; other updates to make the site more appealing will follow
Develop mobile data capture device for landowners e.g. NaturEtrade mobile smartphone GIS app	Yes	Yes	NaturEtrade has been designed to operate on all major portable devices. Usage statistics show that users are engaging with the website and logging land parcels via tablets and smartphones, so this has been a success.
Development of NaturEtrade database structure to enable coordinated upload facility to import and store landowner holdings into landowner account (modelled on myForest system).	Yes	Yes	Additional functionality for incorporating land Registry data directly to supplement drawing tool, adapted from myForest has been a very significant breakthrough, not only technically but in terms of user acceptability and a quality mark for the project
Link EcoSET to NaturEtrade	Yes	Yes	The linkage between Sylva Foundation databases and the ecosystem services and landcover layers held in Oxford has been achieved. Operationally, there have been some occasions where the Oxford servers have failed through proliferation of problems in code, which are difficult to track. These are solved on a case-by-case basis, and the system appears to be stable in late 2016. Problems, however, demonstrate the necessity of employing a technical person who has expertise in fixing code for the After-Life of the project.

Develop interface system linking sellers (landowners) and buyers)	Yes	Yes	The database structure is in place and will be tested in a live setting in early 2017 with buyers and sellers in Surrey, UK. We think we have achieved a good balance of simple-at-point-of-use, and complexity behind-the-scenes. We will monitor how this balance is perceived in stakeholder meetings.
Pilot test NaturEtrade with selected group of key stakeholders in each case study country	Yes	in beta	Early testing (with placeholder landcover data) has been good enough to attract interest from land managers and two water companies. We are confident that full testing will not reveal unforeseen problems.
Review of existing schemes that provide contracts for ecosystem services – what works well, where lessons have been learned etc.	Yes	Yes	Review was not as helpful as we had anticipated in revealing models that would work for NaturEtrade. It did, however, provide evidence that the project is genuinely innovative.
Review of similar web-based platforms, not necessarily trading ecosystem services but utilizing a similar business model - what works well, where lessons have been learned etc.	Yes	Yes	As above. We changed Personnel for this task when it became apparent that our project objectives did not align well with the groups originally tasked with this element. The change of personnel immediately resulted in a more productive working relationship between the Sylva Foundation and the economists. At the same time, key tasks were moved to the Sylva Foundation, which resulted in a much more cost-effective delivery of Action B3.
Devise governance arrangements	Yes	Yes - but anticipate amendments	see note above
Develop and market test pilot contracts with buyers and sellers building.	Yes	in beta	The change of personnel (see above) delayed this task somewhat, but we now have a clear theoretical framework and draft governance arrangements in place which have been discussed with University of Oxford legal services. Those discussions will continue and the governance arrangements will be finalised in 2017

Develop web-based interface for contracts within the NaturEtrade web-platform and business model.	Yes	in beta	Simple contracts have been demonstrated successfully to stakeholders in the UK and will be used for the first real test in Surrey, UK in early 2017. The payment element of the contracts has been discussed with University of Oxford legal services. It will mirror what is already operational for LEFT, which has been signed off by legal services. Dispute resolution may need to be amended in the three non-UK countries and we anticipate that we will not be able to deliver fully-compliant contracts in these countries by the end of the project. We will have developed contracts sufficiently robust to demonstrate the utility of the tool, however, which is we believe within the terms of the GA.
Initial development of land verification system through creation of system to continuously process Landsat-class satellite data to surface reflectance across Europe	Yes	Yes - for UK	By 2017 this will be developed for all Europe.
Integrate contract into NaturEtrade	Yes	Yes	The simple contract structure and ease of producing a contract online has been well received by early testers at UK stakeholder meetings
Targeted capacity building among potential users and marketing strategy	Yes	Partially	We have yet to develop a full marketing strategy. We have identified users for early testing from our existing networks of landowners and managers with whom we have worked in the past, and developed new contacts in a 'snowballing' way from these contacts. The GA sets out clear groups and associations with whom we will work from 2017 once the trading platform is fully operational with data layers that can be checked quarterly. The decision was taken not to engage widely BEFORE this point as our marketing consultant for LEFT gave us clear advice that going early before we had a fully working product would jeopardise future engagement.

Implement land verification tool to run a land cover decision tree classifier using CORINE classes at frequent intervals	Yes	Yes - though not with Corine	The technical report details why Corine was not used and the delay this caused. However, we have a better product and will be able to perform verifications (comparisons over time) from 2017
Build linkage between NaturEtrade databases of land subject to transactions and spatial data granule databases to determine land use change in specified areas and persistence or otherwise of ecosystem service provision	Yes	No	Will be achieved in early 2017 (see above)
Determine rates of land-use change in UK, Croatia, Romania and Spain from 3-monthly satellite imagery; framework for social impact assessment developed	Yes	No	Will be achieved in early 2017 (see above)
Determine case study regions within these four countries based on rates of change and run targeted workshops in these regions to disseminate EcoSET and NaturEtrade to the networks of landowners and buyers	Yes	Yes (exception Croatia)	Region in Croatia will be decided early 2017.
Measure rates of land-use change in selected case-study regions	Yes	Yes	Once region in Croatia is selected, we will measure baseline landuse changes in all countries

Identification of selected stakeholder groups and networks	Yes	partially	We have a strong set of networks identified in the GA and have used our closes contacts to date (through Sylva Foundation's myForest and British Woodland Surveys networks) in addition to contacts developed through LEFT. Once the tool is fully operations (early 2017) we will rapidly develop the network
At least 400 stakeholders registered on database by 30-6-2014	Yes	partially	
Plan and promote workshops for potential buyers of ecosystem services in the four countries and regions identified (i.e. UK, Croatia, Spain & Romania)	Yes	UK only	Other countries will be achieved in 2017. We had no difficulty filling spaces for the two workshops held in Oxfordshire, including with Government policy advisors and land agents. We anticipate similar interest in the other countries. Surrey Wildlife Trust took on the organising and advertising role of the main UK stakeholder even in early 2017, which is testament to the interest shown in the tool and project generally.
Publication of news items, and adverts in relevant publications and newsletters to advertise EcoSET and NaturEtrade	Yes	No	We have deliberately held off this task until we had a fully functional tool. We have engaged in limited publicity on the advice of our LEFT marketing consultant (see above).
Workshops run for potential buyers of ecosystem services	Yes	in UK	See above. The workshops planned for 2017 will be combined landowners/business workshops, demonstrating both buying and selling ecosystem services.
Run knowledge exchange workshops with related LIFE and non-LIFE projects	Yes	partially	We invited partners in another LIFE+ project to attend the second UK workshop in Oxfordshire, but they were unable to come. We have had one very successful meeting in Oxford with people from another LIFE+ project on a related topic and visited their project in return. This is likely to result in collaboration of benefit to both projects.

Disseminate project summary to stakeholders, policy makers and wider public in appropriate formats	Yes	early draft	We have drafted accessible summaries for meetings and our two workshops and will continue to work on user-friendly versions for stakeholders. These were developed following discussions with policy and communication staff at the Oxford Martin School (OMS), whose brief is to make the multidisciplinary research in oxford widely available in suitable formats. The level of knowledge of stakeholders to date has been high and we have found a desire from them for technical information about the ecosystem services in the tool. Advice from them and our marketing consultant for LEFT is that we will need a suite of accessible documents pitched at different levels. We will continue to work with our OMS colleagues to develop communication outputs with impact.
Produce media & policy briefs – including project results and future policy options	Yes	No	See above.
Inception report	Yes	Yes	delayed owing to late starting of project (by agreement with EC)
Progress report	Yes	Yes	As above. We changed Personnel for this task when it became apparent that our project objectives did not align well with the groups originally tasked with this element. The change of personnel immediately resulted in a more productive working relationship
Mid-term report	Yes	in train	Longer delay than previous reports, owing to difficulties reconciling financial reporting. Following our Joint Mission meeting, we hope to streamline these procedures in the future.

5.4 Analysis of long-term benefits

Environmental benefits

Currently one of the biggest threats to global environment and the sustainable management of natural resources is land-use change (around 1500 ha are lost every day in the EU to changes in infrastructure and urbanisation). This directly affects key ecosystem services supporting climate change, natural infrastructure and sustainable use of natural resources. The EU Biodiversity Strategy proposes to reverse biodiversity loss both within and outside of protected areas by 2020 in part by recognising the economic value of ecosystem services and attracting private sector investment. This is particularly relevant to 505 million hectares of privately owned land across the EU, the owners and managers of which are ultimately the target audience for NaturEtrade.

Throughout the duration of the project to date, we have been reminded by a variety of stakeholders of the urgent need for a suite of easy-to-use tools to enable landowners to identify the ecosystem services that their land provides, and a marketplace to trade these ecosystem services. NaturEtrade has already demonstrated technical ability to serve as a novel tool to identify, map and create a marketplace for European ecosystem services. Demonstrating that use of NaturEtrade will lead to lower rates of biodiversity loss may not be possible, but we have been persuaded through engagement with land owners and managers, and businesses who support environmental protection that the tool will of itself raise awareness of land use changes and allow managers to make informed decisions about future changes to their land. Although the tool does not measure 'uplift' (improvement to the land) as the basis for a contract (which is established on the basis of 'no landuse change/deterioration'), the tool encourages uplift by enabling land managers to enter their land parcels in ever-improved states every 12 months at higher selling prices. In this way, environmental improvement is strongly encouraged in an easy-to-use, scientifically robust manner.

This project will directly contribute to climate change adaptation by demonstrating a mechanism to both identify the important blocks of privately owned carbon stocks in Europe and protect them through making them a tradable commodity. It is estimated that in Europe there are currently 73 million ha of privately owned forests and peatlands. In order to stabilise greenhouse gas concentration at a level that keeps global warming below 2 degrees C, and to contribute to the implementation of EU commitments to the Paris Agreement, it is essential that a mechanism for protecting these remaining blocks of privately owned forest and peatlands is developed and that this involves private landowners and businesses in a common goal. NaturEtrade presents an opportunity for collecting important data related to the carbon balance of EU forests and peatlands and marketing this regulating service as part of a tradable bundle of ecosystem services will make entry by private investors an easy and, based on workshop feedback to date, an attractive, prospect.

NaturEtrade, with its ecosystem services assessment and market place will enhance the provision of environmental public goods and will contribute to a number of EU strategic objectives: resource efficient economy, climate-resilient, low-carbon economy, innovation for green infrastructure alongside creating business opportunities.

Socio-economic & policy benefits

The active management of natural resources is essential for the sustainable provision of European citizens with a secure, high-quality, value-for-money source of food and fibre. The improved measurement of ecosystem services at the private landowner level has the potential to change the management paradigm of land users in a fundamental way. For the first time, at the cost of entering the coordinates of their land into a computer or smart phone, or drawing down Land Registry GIS data, they will be able to see the changes in the ecosystem value of their land on the 12-monthly basis, which can later be improved to 3-monthly if the market demands more regular updates. This alone is likely to have a profound effect for enhancing land management – boosting the productivity of existing land under production and increasing the resources devoted to and the effectiveness of conservation efforts.

NaturEtrade will also provide a new potential source of income by formally recognising a new asset class for the landowner – the non-production ecosystem service value of their land. Once this asset is formally and quantitatively recognised in this way, it will then be easier for land owners to lever income off this asset – whether through entering into contractual agreements through the NaturEtrade website, their own bespoke land management plans, or more effectively being able to access conservation funding. Such grant making organisations will also be provided with extra institutional support from the NaturEtrade project through a new tool for programme evaluation, which should boost the long-term effectiveness of the EU's agri-environment policies.

Another source of value will come from the internalisation of the social benefits of ecosystem service provision at the local, national and global levels. These include: water cycle regulation, cultural amenity, wildlife conservation, ecosystem resilience, carbon sequestration and pollination.

The current EU biodiversity strategy encourages the active involvement of civil society at all levels of implementation, citing citizen science initiatives as a valuable means of gathering high-quality data and mobilising people to get involved in biodiversity conservation activities. NaturEtrade has important implications for increasing the knowledge base for biodiversity, a key aim of the biodiversity strategy, by involving individual landowners in the process of understanding the ecosystem services provided by their land, mapping them, documenting them and making the information available in the trading platform. The information collected, clearly, has value far beyond the trading activities. The raw data will be available for scientific and socio-economic analysis, the synthesis of which will contribute valuable information for the broader knowledge base of Europe's biodiversity and ecosystem services. The provision of spatial information (maps) on ecosystem services provided by this innovative approach will also enable this information to be taken into account in spatial planning and land-use management.