

Design of a Transactional Environmental Support System

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ABSTRACT

This chapter draws on results from previous chapters, in some cases creating new syntheses by combining information across chapters and including findings of previous projects. Its specific objective is to consolidate all these findings in the design of a system to support transaction of information for environmental assessments and decision support at central and local levels, by local managers of land and species as well as by policymakers. It recognises the need not merely to provide a technological tool, but also to consider demand and supply for information in that tool, the ease of use of the tool, motivation to use the tool and cost of maintaining the tool long-term: a tool that is not desirable, practical and durable will not last. The chapter therefore first addresses who makes the most decisions, finding not only that local managers of land and species have high need of support, but also that their demand is least met by model-based decision support despite their high capacity to generate data. For this reason a system was designed primarily to accommodate needs of knowledge transfer at local level. Consideration of data quality, ownership and confidentiality was important, together with scale, uncertainty (and resulting liability) of resulting decision support. All these considerations can be addressed by developing trust in operation of such a system, for which a basis in the civic sector (rather than in private business or government) was recommended. A portal was launched to continue informing all interests of the scope for building and opportunities from use of such a system.

INTRODUCTION

The strategic objective of TESS was “to design a decision support system related to environment and land use that will enable policy makers to integrate knowledge from the regional and local level into the decision making process, while also encouraging local people to maintain and restore biodiversity ecosystem services”. Specifically TESS aimed “to design an internet-based system capable of:

- (i) delivering environmental decision support locally, to help local land-users make micro-assessment decisions that benefit incomes and biodiversity, in exchange for
- (ii) a supply of monitoring data that will summate effectively for use centrally, in order to enhance information for government assessments”.

However, in order to provide monitoring data that covers the whole landscape systematically enough to summate for effective government planning, the system will need to be very useful for managers of farms, forests, fishing and hunting areas, gardens and council land, as well as for communities and their volunteers. Above all, a system must be intuitive to use in the context of other necessary tasks. The red, green and blue lines that denote potential spelling, grammar and other mistakes in Microsoft Word are good examples of such context adaptation, based on very extensive computing. In a TESS context, submission of a farm-plan might elicit a response “income will increase to X” but also colour a stream red to indicate likely excessive nitrate run off and flash field areas, such that if the cursor was moved over them a comment would read “Nitrate risk can be offset by increasing buffer strips to 10 m” or “90% risk of halving partridge population can be reduced to 10% by...” A system capable of providing baseline data for SEA and EIA, but also and especially of providing decision support locally for the simplest daily tasks would need to support operation at a variety of scales (Table 1).

Scale	Context/Question	Operation Mode
Field Individual	! BEEP ! HARRIER NEST AHEAD	<i>Satnav seeks to divert harvester for 20 meters</i>
Garden Individual	Is it too early for the Nymphalid butterfly larvae if I cut the nettles?	<i>Intelligent GIS on GPRS-enabled tablet or smart-phone.</i>
Farm Individual	If I use my land like this in future, what happens to my income, game bags and nitrate run-offs?	<i>Guidance on electronic farm plan through colour codes, with comment-bubbles for proposed mitigations.</i>

Parish Community	How do we route this path to optimise views while minimising erosion and wildlife disturbance?	<i>GIS-based modelling with 2D/3D views on desk-top PC by councillors in local community centre.</i>
Region	If trends in land-use continue for 20 years, how can we still meet planned biodiversity targets?	<i>Scenario models of minimal subsidies for leveraging restoration through sustainable use activities.</i>

Table 1. Operation modes of an internet-based Environmental Support System.

Apart from the need to scale for delivering data and decision support at different levels, many other aspects need consideration. These include (1) confidentiality, (2) payments for data where necessary and (3) input in many formats. Delivery of decision support must also address requirements for (4) civil liability for advice given, (5) audit of processes, (6) output in multiple formats and a variety of geographic languages and (7) incorporation of models of many types. Development of such a system is of necessity a very long-term exercise, and must therefore (8) be based on durable yet replaceable software for expansion to handle huge information loads, (9) have ability to interface with proprietary software yet avoidance of reliance on it, and (10) involve appropriate governance and funding agencies. Although public funding is important for initiation, this must not preclude a subsequent balance of public, private and voluntary resources, to ensure funding in the long-term and that the system remains responsive to the needs of users. A system that transacts locally-based monitoring for centrally-provided decision support will self-fund, for long-term development, only if it effectively meets user requirements at all levels.

In order to deliver support required by central and local levels, TESS needed to understand what information is required at the different levels, what is available and where there are gaps. The next section of this chapter is an overview of the requirements and gaps in knowledge indicated in previous chapters, followed by a consideration of the needs for maintaining data quality, ownership and confidentiality, and for handling uncertainty in a decision support system. The consideration of technical design for the system precedes a section on social design, in the form of market surveys that involved launching an information portal to continue after TESS.

BACKGROUND: REQUIREMENTS AND GAPS IN KNOWLEDGE

The TESS process involved planning and trial questionnaires at national level for 9 countries in WP2 and at local level for 8 countries (Chapters 2 and 3), leading to a synthesis of information flows (Chapter 4). The survey protocols were then refined and applied in the Pan-European survey, again for national administrations (30 countries), local administrations (28 countries) and local stakeholder categories (Chapters 6-8).

Capacity for generating information at local level was examined in the surveys and also in case studies in 9 countries (Chapters 9-19), which collected information on capacity for mapping and socio-economic investigation by local volunteers, and on participation and spending of rural inhabitants in various stakeholder activities. The capacity to gain information from models was examined in Chapter 5, by creating a database containing the models considered most suitable for supporting farming, forestry and recreational activities affecting biodiversity.

At what Levels are Decisions made and by Whom?

Information is needed for environmental decision making, which inevitably becomes denser at lower levels. Decisions at EU level that result in Directives and hence national laws are much rarer than the number of environmental assessments created by those laws. Numbers of the assessments (SEA+EIA) are variable across countries, but average about 2.5 per thousand km², or less than one per year at lowest level of government administration (LAU2). However, LAUs typically take some 3-20 environmental decisions annually, because they also make land use planning decisions for developments usually covered by strategy but not qualifying for EIA, and they also manage council land in parks and schools and along

roads, etc. Each private manager made about as many local decisions as a council (Chapter 7). However, as the areas of local council decisions tended to be smaller than those of private land managers, and as there were many such private managers in each LAU2, private managers (except fisheries) had decision densities 4-5 orders of magnitude greater than local authorities.

Pan-European surveys, and case studies, also asked local councils to estimate proportions of the residents in their administrative areas that engaged in a range of outdoor activities, and compared those figures with proportions recorded among residents surveyed. Local authority estimates in case study areas averaged about half the proportion recorded among residents; the 3-5 local authorities selected randomly in Pan-European survey had still lower estimates (Figure 1). The importance of this gap in knowledge about participation in countryside activities was shown by asking individuals to estimate their annual spending on these recreations. Average household spending was about €850 on rural recreation. For activities that required wild species, this was €145 on hunting and fishing, €100 on providing food or making excursions to view wildlife and €14 on gathering wild products (Figure 3 in Chapter 9). If this was representative for the EU, grossing up from an independent estimate of €35 billion total annual spend on hunting and fishing (Kenward *et al.* 2009) gives a total private biodiversity-dependent spending of €62 billion. There is therefore an important knowledge gap in European governments about the level and value of participation in recreational activities involving biodiversity. Yet this has been surveyed in North America since the 1980s (USDA, USDC & USFWS 2007).

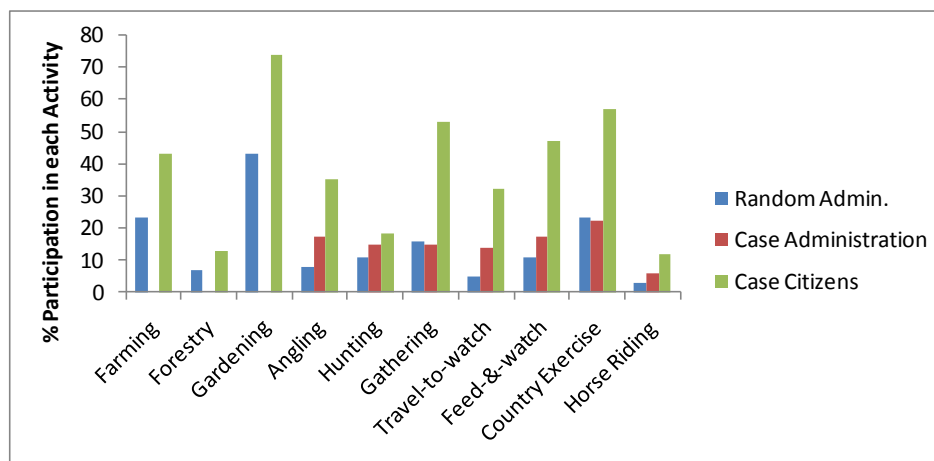


Figure 1. Administrations in case studies deemed participation in countryside activities higher than in random areas nationally but under-estimated actual engagement of case study citizens.

Information Flows during Decision-Making

National and local governments, and stakeholders, were asked about sources of information for decisions on the environment. All turned to government and its agencies for about 30% of their guidance and to publications for about 10%. Local people made much less use than national governments of NGOs and consultants (Figure 2), whereas local knowledge (including personal records) was used more extensively at local level; hunters were most extreme in this respect. National governments did use some local knowledge, but rather little of this was on habitats, whereas information on habitats dominated the needs of managers (Chapter 7).

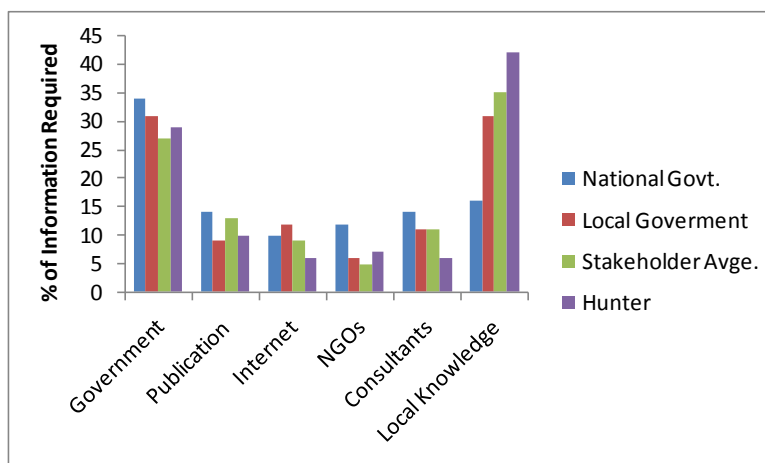


Figure 2. Sources of information cited for addressing environmental decision-making by national and local governments, private local managers (averaged) and hunters.

Digital information at local and higher levels

It was clear from the surveys that a great deal of useful local information was being gathered at local level, but how much was digital? Among citizens surveyed in rural case studies, 65% of households were using the internet, though use tended to be much greater in some states (64-100% in Estonia, Greece, Hungary, Poland, Portugal, UK) than others (17-22% in Romania and Turkey). Digital enablement of local authorities was also reasonably good in about half the countries surveyed. In the Pan-European survey, local authorities were asked if they recorded species data digitally, systematically or occasionally, and whether they used and could name a GIS system. Local authorities in more than half the countries scored at least 3 out of 5 (see Figure 11 in Chapter 7).

Thus there is considerable demand for habitat information at local level, with computer and GPS skills (demonstrated in the case studies) for using it. However, it was also clear from interviews with local stakeholders and officials at the two lowest tiers of government, that finding and accessing current data at an adequate scale and accuracy is a problem at local level (see Figure 5 in Chapter 3). So what about the ability to generate digital information locally? Case studies showed that the capability of local volunteers to generate information in digital format is very good if they are provided with suitable tools (Figure 3).

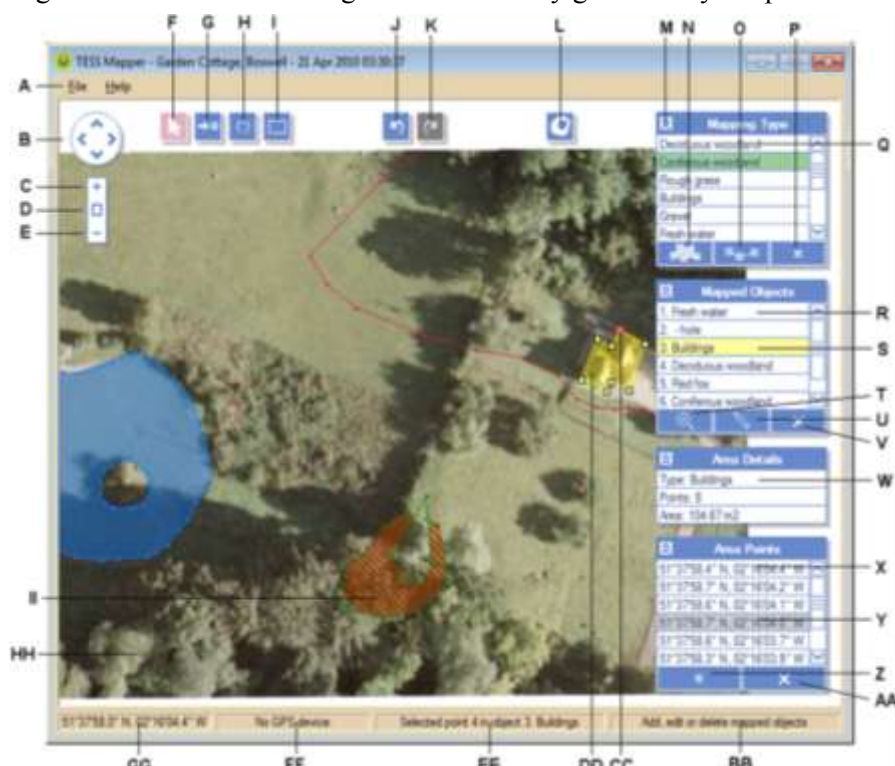


Figure 3. The mapping tool in TESS was designed for use from 6 years of age; it enabled habitats to be drawn over photographic or other images, used on desktop computers and tablets in the field, with GPS assistance if required, and had Graphic User Interface and Help files translated into national languages in all partner countries.

In the case studies, local mapping was not only highly proficient but also enjoyed (Chapter 9). On a scale of 5, 98% scored 3-5 for gain in knowledge (53% scored 4), 95% for likelihood to do such a project again (46% scored 5); 96% thought such work should be supported nationally.

At European level, CORINE data are an important resource for indicating broad changes in land use. Local knowledge is challenging to collate, so it is unsurprising that local information is not used to a greater extent at national levels (Figure 2). However, as the Pan-European survey found that 86% of the countries across Europe require maps from farmers as a condition of CAP agri-environment payments, and that in all but three countries these can be digital (Chapter 7), it is disappointing that more is not being done at high level to compile such material for use at all levels.

Nevertheless, databases of species records that are organised at national and European level are becoming increasingly effective for use at national and international levels (e.g. the SEBI indicator on farmland birds), with increasing user-friendliness of web-based versions for use by interested individuals and local authorities. Moreover, the success of citizen-science initiatives, including Eye-on-Earth projects organised by EEA and Open Air Laboratory (OPAL) projects run from the UK Natural History Museum give confirmation from outside TESS of enthusiasm for recording information on species and other aspects of the environment.

Focussing on Local Level

After a consideration of indicators, species databases, local mapping and high level GIS, it is time to consider the potential of models for decision support at various levels. In practice, TESS chose to focus its review of models on suitability for decision support at local level for four reasons. One reason was that most other prominent projects in FP6 and FP7 tended to focus on the science-policy interface, offering support on distributions (e.g. EBONE), hazards (e.g. ALARM), models (e.g. COCONUT), databases (e.g. EUMON), strategic assessments (e.g. LIASE), integration for GMES and GEOSS (e.g. LIFEWATCH) or policy directly (e.g. SPIRAL), but not for local level decision makers. Beyond research, implementation approaches such as IPBES and the whole structure of CBD-SBSTTA are also focussed at the science-policy interface.

A second reason was a consideration of previous decision support systems at landscape scale in the UK. The NERC/ESRC Land Use Programme (NELUP) was successfully implemented at Newcastle University in the 1990s and used to answer questions about river catchments (Benson 1995, O'Callaghan 1996), but no long-term user was identified for the system. A prototype Environmental Information System for Planners (EISP) was built for operation at Tier 2 (District) in the UK (Culshaw et al. 2006), but planners at that level saw its value only for training or to guide submission of plans from individuals at lower level. A Land Management Information System (LaMIS) developed by a 3rd tier authority (Hampshire County Council) conceived the idea of integrating local mapping to an extensive GIS coverage but had little useful to give in exchange for the maps (though the possibility of decision support was mentioned at a discussion meeting). By setting out to provide decision support for the lowest level, where authorities and individuals are now more computer savvy (Chapters 8-9), the TESS design should overcome problems that affected the uptake of these technically strong but socially unsound projects.

The third line of support for providing decision support to local level was an FP6 project on Governance and Ecosystem Management for Conservation of Biodiversity (Manos & Papathanasiou 2008). Analysis of case studies at local and national levels showed that the governance factors most associated with conservation and sustainable use of biodiversity were knowledge leadership and adaptive management (Kenward *et al.* 2011). Scores for adaptive management reflected whether monitoring occurred and if management was based on it. Knowledge leadership was scored from frequency of seeking guidance from one or more sources at higher level. The provision of a decision support system for local level would both provide knowledge leadership and facilitate adaptive management.

Finally, in the analysis of factors from the Pan-European survey (Chapter 8), an important factor reducing artificialisation of habitats was the density of environmental assessments (EIA+SEA). The factors most associated with frequency of formal assessments were not high level regulations but local factors such as consultation, and especially the presence in local authorities of positive attitudes to the benefits of biodiversity and other ecosystem services. Thus, totally separate evidence from (i) those constructing pioneering systems, (ii) a survey of case study governance, and (iii) a study of factors associated with EAs across Europe in TESS all point to the importance of knowledge leadership for local level.

Use of Models for Local Decision Support

As described in Chapter 5, the TESS database was based on the Ecobas Register of Ecological Models and other sources, with searches in Google for models linked to specific keywords, and national knowledge of the 14 TESS partner organisations. Among approximately 2,400 environmental models estimated to be in databases, 198 were initially deemed suitable for researchers and managers of land, freshwater and species.

Subjects covered by these models were compared with those listed as issues by local authorities in the Pan-European survey. There was an abundance of models for provisioning services (agriculture, forestry, aquaculture, fishing), reasonable numbers for hazards (floods, fires, zoonoses) but relatively few for biodiversity and amenity considerations (Pirimäe 2011). A further conclusion was that whereas knowledge was relatively abundant for supporting and provisioning services of ecosystems (see Table 6 in Chapter 5), it was much less adequate for management of biodiversity, regulating services of ecosystems (which reduce hazards) and for cultural services (in which services for recreation and amenity can include biodiversity).

However, the consideration of the usability of models by scientists who develop them does not mean that information from them is necessarily available to local managers of species and ecosystems. The database was therefore examined by two partners other than the one that constructed the database, to see what proportion of models would be available to local managers of the countryside, assuming they understood English. Among the 198 models, some of which had been registered in the 1990s, there were 143 (72%) that could still be traced on the internet. However, this independent assessment found only 99 of the 143 (50% of the total) to be potentially usable at local level; finally, 89 of these were found to be either not accessible as downloads or web-services or, after further cross-checking by a partner specialising in easily-used software, not user-friendly enough for non-scientists. Thus, only 10 models (5% of 198) were considered possibly usable by local managers of land, freshwater and species (Figure 4).

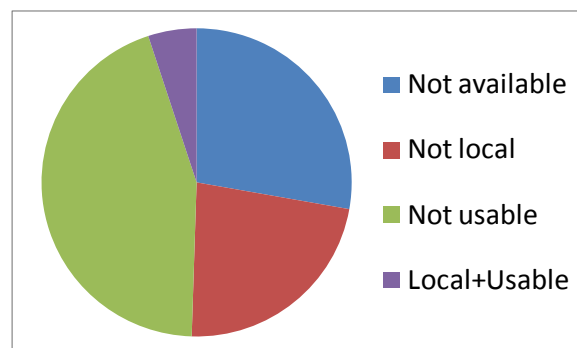


Figure 4. The proportion of 198 initial models in the TESS database that were not available as downloads or web-services, not suitable for local level, or not user-friendly enough for local managers of land, water and species.

As a check on the efficacy of the survey process, an independent check was made on 195 models in Ecobas that were not in the original TESS database. Of these, the proportion that could still be traced on line fell from 72% to 31% and none were considered usable by local managers of land, freshwater and

species. It could therefore be concluded that the TESS database contained the most relevant models and that usability of the models by local managers of land, freshwater and species would not rise above 5%. The models were being written by scientists for use by themselves and other scientists, with minimal technology transfer to those actually managing the resources. Moreover, among all 205 models that were traceable, only 2 (both in the USA) were making use of large external databases.

After considering the topics covered and the ease of use by local managers, a third issue investigated was language. Of the 10 models that were technically suitable for local use without special training, two were in Hungarian and 8 in English, in one case also in French. This would further constrain use by local managers of species and ecosystems.

In conclusion, this section has examined 4 main types of information: (i) GIS coverage prepared at high level by remote sensing, (ii) species databases, (iii) models as in other databases and (iv) local mapping. We have also considered the use of information for (a) strategic assessment indicators to inform high level policy, (b) environmental assessments (SEA+EIA) at lower level, (c) NGOs and consultants that guide local stakeholders and (d) the local managers of land, water and biota. The findings are summarised in a qualitative way in Table 2.

		INFORMATION DEMAND showing also outcomes (and constraints)			
		High level policy	Local environmental assessments	Stakeholder NGOs & consultants	Management by local stakeholders
INFORMATION SUPPLY	Government remote-sensed GIS +indicators	Available, Used	Available, Somewhat used (penetration)	Partially available, Somewhat used (penetration, usability)	Partially Available, Little used (penetration, usability)
	Private databases of species presence	Available, Used	Partially available, Used (penetration)	Partially available, Somewhat used (penetration, cost)	Partially available, Little used (penetration, cost)
	Databases of public+private predictive models	Suitable, Used	Sometimes suitable, Somewhat used (accessibility, usability)	Sometimes suitable, Little used (accessibility, usability)	Sometimes suitable, Not used (accessibility, usability)
	Local mapping and other knowledge	Not available, Not used (diffusion, privacy)	Partially available, Somewhat used (accessibility, privacy)	Available, Somewhat Used (penetration)	Available, Used

Table 2. Gaps at different levels of society in the availability and use of information needed to manage biodiversity; white shows adequate matching of supply and demand, dark grey shows inadequacy, with and bold text indicating serious gaps in information and technology.

The worst problems are that although predictive modelling is used for assessments at national and international level, and in some cases by experts and consultants for local level, it is not easy for individual stakeholders to use. Conversely, local fine-scale mapping is done by stakeholders and used by their NGOs and consultants, but privacy issues hinder use by local authorities and there is no integration for use at high level. Yet the sort of modelling needed to predict populations of small species, and hence to restore biodiversity by re-diversifying land-use, needs much higher resolution over large areas than the remote sensed data in CORINE.

At local level, decisions on what and how to cultivate land are significantly shaped by government policy, but are also inescapably constrained by factors such as local soil, social considerations (including recreation), species, topology and weather. Combining local mapping with the information from above should facilitate decisions for diverse use of land and species (hence biodiversity) that embrace the variety of these local factors, whereas remote markets, regulations and other incentives tend to homogenise land-use. It also seems appropriate to assist the management of local recreations which depend on biodiversity, because activities such as angling, hunting, gathering and watching wildlife, involve private spending of at least €40 billion annually in Europe, and hence can benefit livelihoods if nature remains diverse and abundant.

With all these considerations in mind, the design that we develop in the remainder of this report is a long-term socio-economic support system and outline technology for an “intelligent” GIS (iGIS). Our proposal is to develop for GIS the equivalent of the spelling, grammar and sense checking that was introduced to help make best use of the first, simple word-processors.

HANDLING SCALE, DATA QUALITY, OWNERSHIP AND CONFIDENTIALITY

Scale and confidentiality may seem a strange combination. However, just as personal identity of a digital image can be lost by enlarging the scale of pixels showing the face, so too can details of spatial data be blurred. Different actors in collecting data on species and habitats, including remote sensing (e.g. satellite imaging), scientists, landowners and volunteer recorders have different capabilities for recording detail and different concerns regarding data confidentiality.

Scale

A frequent concern in handling data on biodiversity is that of scale. At different scales, there are issues in terms of measurement and in the ability to use predictive models for forecasting spatially specific changes in species populations.

Modelling and measurement at small scales

One sort of model, called ‘individual-based’ when first used in ecology (but now more widely known in human applications as ‘agent-based’), simulates the performance (including production and loss) of each individual interacting with its environment and then aggregates to estimate population level parameters such as emigration, birth and death rates, and hence population sizes (Goss Custard 1996; Sutherland 1996). In contrast to this approach the more common option is for population densities in different places or times to be measured and modelled with associative statistics in relation to habitat, climate and other factors in the environment. Individual-based simulative models can require much more data on an individual’s fate to formulate reliable predictions than the associative statistics approach. However, this higher input (and cost) of information tends to result in the ability to predict consequences beyond the range of environmental conditions used to build the model, especially in non-linear situations. For example, an agent-based model incorporating a minimum territory size may predict that a population will not increase beyond a certain size however much food occurs, because all offspring will emigrate, while a model of association between numbers and food supply would predict a continued increase in density, with no effect of territory size.

This is a slight oversimplification, because intermediate types of model with associative and individual-based properties are possible (South *et al.* 2002). Models are therefore sometimes referred to as deterministic instead of associative (Figure 5).

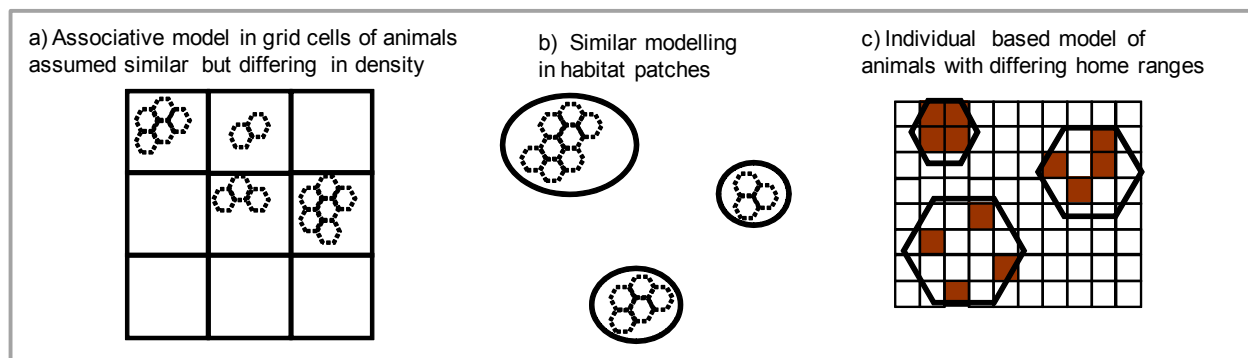


Figure 5. Different types of model for forecasting changes in species populations.

Diffusion processes may also be used when considerations of animal and plant dispersal need to be taken into account to model colonisation processes (Kenward *et al.* 2002). Such models may simply estimate spread rates, for example of diseases, without needing to be spatially specific (Figure 6a), or dispersal between patches that hold metapopulations without modelling routes (6b), or model the routes used too.

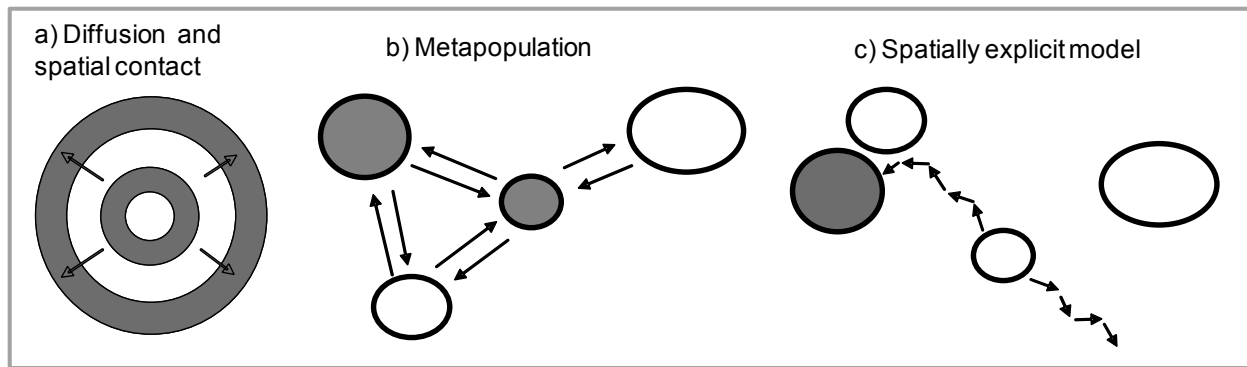


Figure 6. Different types of model for forecasting colonisation processes, without being spatially specific (a), by modelling dispersal rates between patches (b) or by modelling detailed inter-patch movements (c).

How are data and computational requirements of individual-based modelling affected by scale used for population forecasting? Let's imagine an area of one hectare (100x100m), the size of a large garden. In 1 ha, it is possible to measure a population of hundreds of plants, the butterflies that feed on them and simulate their interactions. However, modelling ants and their parasites in 1 ha would challenge the capacity of a personal computer. Conversely an area of 1 ha would be far too small to provide the information needed to model the population of a large vertebrate predator.

In principle, a solution for the ants is to break up the 1 ha into sub-units, of perhaps a million units of 1 square metre, and for the predator, to aggregate into a million hectares (100x100 km²). At small scales there may be serious challenges not only in computing but also in measuring the factors important for species. Weather can be measured and predicted at 100 km scale, but what about variation in soil pH that may greatly affect the plants and hence the insects? Perhaps soil pH can be estimated to some extent from a map of underlying geology, but it will also depend on past vegetation and cultivation conditions.

The result is that associative modelling may be the only practical means to measure and adequately predict biological consequences at small scales. It may therefore, at least until computing and measurement capability improves, be most practical to work with habitats rather than individuals for small animals and plants. But how small? This will depend on the accuracy with which species and habitats are mapped.

Recording distribution of species

A review by WWF-Turkey found 28 websites which record species in a variety of taxa across Europe (Table 3). Most are accessible in English but few in more than one other language.

Country	Site	Url	Language	Data Mapped	Data Search
Global	Animal Information - Information on Endangered Animals	http://www.animalinfo.org/	EN	No	Yes
Global	Global Biodiversity Information Facility	http://www.gbif.org/	EN	Yes	Yes
Global	Birdlife/RSPB/Audubon global database	http://www.worldbirds.org/	EN,FR,ES,PT,AR	Yes	Yes
Europe	EUNIS	http://eunis.eea.europa.eu/	EN	Yes	Yes
Europe	European Bird Census Council	http://www.ebcc.info/pecbm.html	EN	Yes	Yes
Bulgaria	Bulgarian Biodiversity Portal	http://chm.moew.government.bg/indexE.cfm	BG,EN	Yes	Yes
Denmark	Danish Biodiversity Information Facility	http://www.danbif.dk/	EN, DK	Yes	Yes
Denmark	Danmarks Naturdata	http://www.naturdata.dk/	DK, EN	Yes	Yes
Denmark	Dansk Ornitologisk Forenings database for bird observations	http://www.dofbasen.dk/	DK	Yes	Yes
Finland	Levavahti	http://www.iarwiki.fi/wiki/Levavahti	FI	Yes	Yes
Finland	Lumonet	http://www.environment.fi/default.asp?contentid=387936&lan=EN	FI	Yes	Yes
Finland	Nature Gate	http://www.luontoportti.com/suomi/en/	FI	Yes	Yes
France	The French Information System on Saprophytic Beetle Ecology (FRISBEE)	http://frisbee.nogent.cemagref.fr/index.php/en/	EN,FR	No	No
France	Suivi Photographique des Insectes POLLINISATEURS (SPIPOLL)	http://www.insectes.org/spipoll/suivi-photographique-des-insectes-pollinisateurs.html	FR	No	Yes
Ireland	National Biodiversity Data Centre	http://www.biodiversityireland.ie	EN	Yes	Yes
Ireland	Species.ie	http://www.species.ie/	EN	No	No
Norway	State of the Environment Norway	http://www.environment.no/en/	EN, NO	Yes	Yes
Norway	Bird and Mammal Identification (Nord-Tondelag University)	http://www.birdid.no/	EN,BG,NO,MA,PO,LV	No	No
Spain	Global Biodiversity Information Facility in Spain	http://www.gbif.es	EN, ES	Yes	Yes
Turkey	Nuhun Gemisi	http://www.nuhungemisi.gov.tr/	TR,EN	Yes	Yes
Turkey+	Kuşbank	http://www.worldbirds.org/v3/turkey.php	TR,EN	Yes	Yes
UK	National Biodiversity Network's Gateway	http://www.nbn.org.uk/	EN	Yes	Yes
UK	Biological Records Centre	http://www.brc.ac.uk/	EN	No	Yes
UK	Natural England	http://www.naturalengland.org.uk/	EN	Yes	Yes
UK	The Open Air Laboratories (OPAL) network	http://www.opalexploration.org/	EN	No	Yes
UK	Game & Wildlife Conservation Trust - Research & Surveys	http://www.gwct.org.uk/research_surveys/wildlife-surveys/default.asp	EN	No	No

Table 3. The sites, languages and some characteristics of European species record sites

The records provided in this way are adequate for monitoring the area covered by a species (distribution) and time (phenology). With a high intensity of recording they could be used for associative modelling. Organisations involved in avian research and protection (which have remained separate in a number of countries) have begun devising internet recording systems for volunteers across groups of countries (see Table 3 and e.g. <http://www.bto.org/volunteer-surveys/birdtrack>). Systems for other popular and conspicuous taxonomic groups like butterflies are being developed as well, with databases at national

level combining the records for different taxa (e.g. <http://www.nbn.org.uk/>) and providing information to the Global Biodiversity Information Facility (<http://www.gbif.org/>)

Current observer density and commitment gives reasonably systematic coverage of presence/ absence at 10 km² level in several countries. With increase in popularity and ease of recording, 1 km² resolution might be possible systematically in some areas. Data of these types are effective for recording trends in distribution of conspicuous species and could be used to test predictive models. In order to build associative models at the same scale, detailed observations at standard sites are required. This is possible with well organised professionals, for example through Long Term Ecological Research (LTER) sites and the ALTERnet capacity building programme for professionals, and the general increase also in volunteer networks.

Building agent-based models requires detailed data on individual plants, animals and their interactions with each other and the environment. Increasingly, such data can be recorded automatically, for example through satellite telemetry at Ultra High radio Frequencies (UHF) on smaller and smaller animals or satellite recording of individual tree growth and death. In both cases skilled support is required on the ground, and increasingly there is scope for training volunteers in these areas. A recording accuracy of 10m has been routine for some time with ground based (VHF) telemetry and this is now practical for larger insects. In view of the detailed understanding required for this skilled volunteer work, there will be a need to translate instructions into the major native languages in Europe to make cross border projects possible.

Mapping habitats

Satellite technology has been used to record land-cover across Europe since 1990 in the CORINE system (Chapter 6) and a resolution greater than the standard 25 ha units is possible in some areas. Indeed, 25 m resolution was obtained from Landsat imagery in 1990 for the Landcover Map of Great Britain (LCMGB) prepared by Centre for Ecology & Hydrology (Fuller *et al.* 1994). By using Landsat scenes from summer and winter, it was possible to discriminate between woodland that was deciduous and evergreen, and determine whether farmland was arable by virtue of being bare ground in winter. Other knowledge-based processing was applied to give a total of 25 land-cover categories (Figure 7).

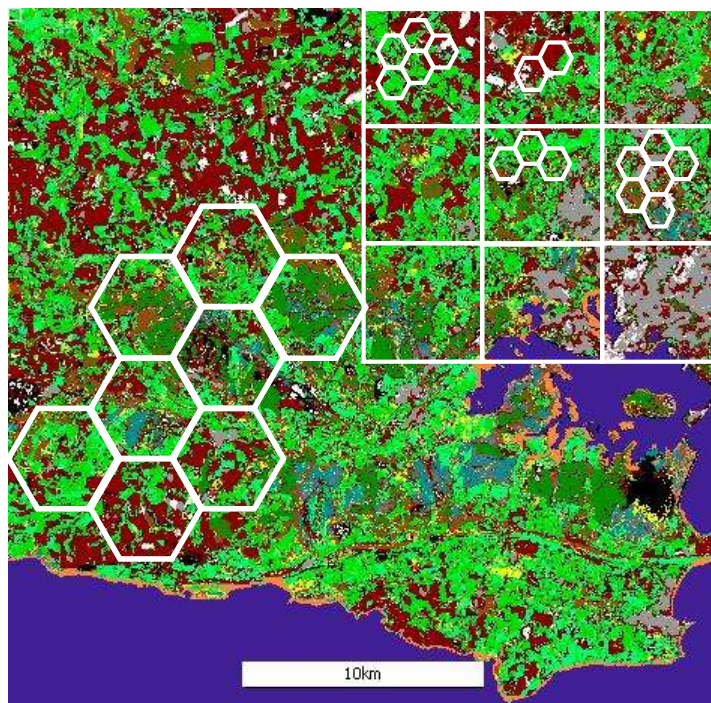


Figure 7. A scene for coastal Dorset from LCMGB, indicating how home ranges of 5 km and 1 km diameter might be modelled in sufficient detail for individual animals (the black area to the south east shows where a cloud obscured part of one image).

Such maps are extraordinarily useful for defining habitat categories in a standard way across large areas, but have three major disadvantages compared with mapping on the ground:

1. The number of classifiable categories is limited to easily distinguishable land-cover types.
2. Satellites cannot easily discriminate changes in vegetation under canopy and in water.
3. On the ground, plotting of point locations for species and lines around areas of habitat can give much finer resolution than 10m.

Ground-based mapping can record many more vegetation categories. Even where satellites can plot large species, such as single trees (at 5-10 m resolution), they cannot image the individual leaves allowing the tree to be identified to species. Raster (satellite-based) images also differ in structure from vector (ground-based) maps (Figure 8).

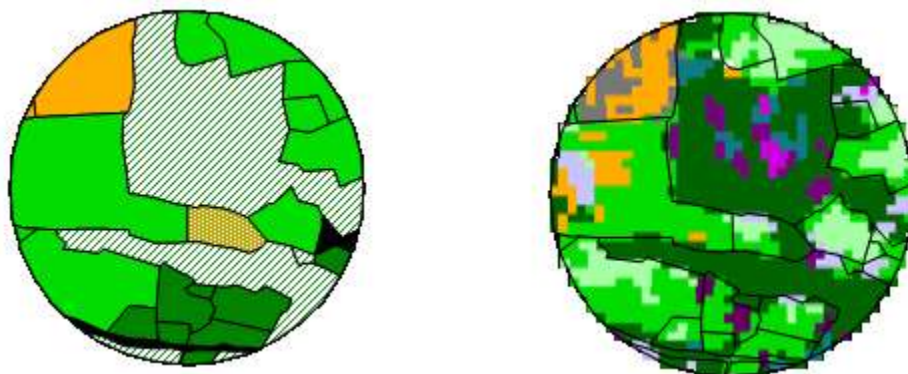


Figure 8. A vector map (left) and raster based map (right) of the same view, showing differences in classification of woodland (hatched), arable (orange) and other habitats.

Fig. 8 shows that although raster-based images from satellite data can be converted to vectors i.e. polygons of similar habitats, the edges of these are less accurate than those from a map originating as vectors from ground mapping. There may also be ambiguity about the make-up of individual polygons. As the capability and interest of volunteers increases, it may be practical to map larger and larger areas as vectors. An intermediate stage, given the growing capability of volunteers with GPS (Chapters 9-19) could be for volunteers to assist in ground-truthing of raster maps derived from satellite imagery and hence speed the production of these at fine scale.

The fine resolution of vector maps (Figure 8) is limited only by the accuracy with which the polygon corners can be plotted. With enhanced GPS, resolutions of 1 m become possible, which suggests that this could become a medium-term target for large cross border mapping projects allowing many socio-ecologically meaningful linear features to be mapped (e.g. paths, road verges, flower beds). Vector mapping at 5-10 m resolution is appreciably less time-intensive for volunteers mapping different categories of vegetation in semi-natural habitats.

Mapping socio-ecology

Just as geo-referenced records of species and volunteer mapping could aggregate to give more complete coverage of species and habitats, so too could geo-referenced economic data. Inputs and outputs estimates for individual fields are increasingly (with GPS-aided farming) being refined for parts of fields. An important principle here is the cost-offset approach from Kenward & Garcia-Cidad (2005), as shown in Box 1, which can aggregate to scenarios such as in Newton et al. (2012). The sum of these inputs and outputs for fields (or part-fields) gives the figures for the farm, which can in principle be summed for farms in an administrative area and for a country. However, the use of exact data from fields, as opposed to general estimates, would raise confidentiality issues that a system must overcome to be truly effective.

Box 1. An illustration of simple environmental economics for decision support on land-use.

If land gives annual income per hectare of I from intensive production, the reduced income from constrained use C should be acceptable if compensated by income U per hectare from use of wild resources:

$$C + U \geq I$$

This equation (Kenward & Garcia Ciudad 2005) shows very simply how ecology and economics can be integrated to support decision decisions about land-use, but can also accommodate social aspects if measurement of C , U and I is extended from income per hectare to employment or to indicators for quality of life. With many possible types of land use and resource use, and the need for sustainability, the calculation process becomes a more complex matter of C_{ij} and U_j for i crop types j types of wild resource use, so that sophisticated computation would become essential for the decision support process.

The equation $C + U \geq I$ uses value from use of wild resources to leverage biodiversity through minor constraints on crop production. There is also the possibility of leveraging U with stewardship subsidies S to maximise scope for conservation:

$$C+S+U \geq I$$

This represents a much substantial improvements from the system of perverse CAP subsidies represented by $C+U \ll I+S$, which is now mostly dismantled. More positively, there have also been European examples where $C+U \geq I$ without subsidies. For example, where food shortage for deer in conifer plantations results in an uneconomic venison harvest and severe bark-stripping, a small loss of timber through including some deciduous trees can be more than offset by gain in value of deer and reduced damage (Reimoser & Reimoser 1997).

Data Quality Considerations

The identification of some species can be taught very quickly even to naive volunteer observers, and methodology for this is constantly being improved. Bird recording has found that within a group of naive volunteers, turning different individuals into experts on different species gives ‘ownership’ and enhances interest and performance of the group in identification. However other taxa may not be differentiated without microscopic examination or even DNA techniques; their monitoring will remain a specialised subject. For the conspicuously different species that volunteers consider to be interesting subjects, automated image recognition by smart-phones is a promising prospect, albeit more practical for easily approached subjects like flowers, and progressively more challenging for motile species like butterflies and shy birds.

The classification of habitats raises similar issues. Categories of habitat may reflect in some cases groups of single species and in others a matrix of species that typify EUNIS habitat categories. TESS mapping in contained areas of such bush species (sea-buckthorn *Hippophae rhamnoides* in Romania: Chapter 16; gorse *Ulex* sp. in UK: Chapter 19) as components of fine-grained habitat: volunteers needed to be able to identify the individual species and the habitats. Where habitats contain key species, the same image recognition approach could be applied as for species. Again, classification experts need to engage with volunteers to ensure that accuracy. Indeed, professionals need to be encouraged to view volunteers as helpers in obtaining data, who need to be trained to be maximally effective in assisting the experts, rather than as potential competitors. Professionals need to be involved in developing techniques and technology that are likely to provide as much quality assurance as possible for data gathered by volunteers.

The need for professional experts to engage with volunteers is one of the key issues in the development of conservation through citizen engagement. The mapping projects in TESS showed mapping by volunteers, with proper training, to be as effective as that undertaken by professionals in terms of polygon placement, and to have similar accuracy in classifying habitats. All environmental data tends to contain inaccuracies: data collected through remote sensing by professionals may be appreciably less accurate than data obtained through ground based mapping (Figure 8). For society as a whole, the question is whether it is more important to do as much conservation research and restoration as possible, albeit with some observation error, or to ensure that only professionals are engaged, in the expectation of fewer errors.

Ownership and Confidentiality

Whereas quality of data from volunteers was the issue raised most by scientists, the most common issue for stakeholder organisations, including those for volunteers, was ownership and confidentiality of data. Most people would accept the principle that, if data are collected by European governments, under Freedom of Information legislation they should be freely available to the public, which pays for the work through taxation. However, many governments find it hard to provide facilities for collecting and distributing these data unless this obligation is placed on them by the European Commission.

European national governments (reacting to European legislation) conduct environmental assessments which require data. In order to fulfil this legal obligation, these governments often contract agencies or private organisations, which may use staff or volunteers to collect the data for the assessments. Often the assessments may become publically available but the raw data does not, perhaps because the organisations wish to use it for more contract work to support their activities. The governments involved may actually favour this approach because it enables them to obtain information at less expense if others are helping to pay for it. It can also suit governments to privatise data sets, so that the holders charge other users, but maintain free access for government use. For governments to save taxpayers money like this is reasonable, but unfortunately privatising data produces costs for public access that inhibit widespread use. In the interests of transparency, data gathered for statutory assessments and to generate environmental indicators should probably be freely or cheaply available to the public.

At first sight, it would seem even more appropriate that data provided to government in exchange for subsidies under the CAP should similarly be made publicly available. However, we must consider the rights to privacy of individual landowners who supply the information. They may not wish to share with potential market competitors, including neighbouring landowners, information that could be considered commercially valuable. For a Pan-European system, solutions to problems of ownership and confidentiality are needed. Indeed, for the system to be widely used, it must engender a high level of trust by showing that it is addressing these issues very thoroughly in the short term and that the measures taken will be sustained in the long term.

Ownership can be addressed by ensuring that all data in the system is tagged to indicate its accreditation. This is essential for any data of commercial value, in order to make payments. However, it is also desirable for data which is free to use, so that those providing such data can have the satisfaction and, where relevant, professional credit for providing societal value.

Data tagging

In addition to identifying data for ownership purposes, tagging can also be used for quality control and to address confidentiality. Three levels of confidentiality are conceived: strictly private, accessible to the system and open to all. Strictly private data will remain resident on the owner's computer or server, on which some computation can be applied through downloaded modules. If passed to the system for computation, these data will be treated securely and erased from all system memory after use. Data input by individuals will, by default, remain strictly private and not pass beyond their computer unless they actively submit it for computation at higher level.

Data that are accessible to the system will be used for computing, but outputs involving such data will be controlled such that detail may not be revealed in text or image below an acceptable level. For example, crop data might be aggregated for display on a 1 km scale (as used currently for the Countryside Information System in the UK), but profit data only on a 10 km scale or at LAU2. Data-owners may choose to make their data accessible to the system, in exchange for which (in a transactional system) they will be given privileges. They may also choose to make data open, and benefit from additional privileges.

The system will need to have basic models built-in. It will need both associative and simulative modelling that transfers the data input into cells of sizes appropriate for particular conservation scenarios. Scenarios

must be built in for automated operation and translation of outputs. The intention must be for the system to attract sufficient funding to be able to commission scenarios and scenario-specific models. Moreover, payment may be needed for use of models that add value to data. Therefore it is proposed that the system treats models as modular components that can be tagged in a similar way to data for handling accreditation and quality issues.

Extensive use of simulative models is likely to become demanding on computational resources, possibly requiring distributed computing techniques and potentially being either expensive or delayed. System users will need to be alerted to this when choosing options. In a transactional system, use of models which are expensive to compute may need to be based on privileges earned through data provision. To include ownership, data-tags will probably need to refer to an address in a meta-database, in which all necessary details can be stored securely. However, other identifiers may best be appended to data and models, including quality and uncertainty codes (which might be combined) and confidentiality rating.

HANDLING UNCERTAINTY IN A DECISION SUPPORT SYSTEM

The user of the TESS decision model may have to make decisions with less than perfect knowledge. The Cynefin model is useful in this respect as it clearly identifies four decision spaces (Snowdon 2002; French & Geldermann 2005) (Figure 9). In the *known* space, cause and effect are completely understood. Thus, decisions relate to actions, the consequences of which may be completely known and accurately predicted e.g. planting a woodlot results in less land available to plant crops in a ratio of 1:1. Cause and effect is also understood in the *knowable* space, but insufficient data are immediately available to make complete forecasts of the consequences of an action. Thus, for example, the yield loss associated with planting a woodlot can be predicted from the area of land loss but there may also be loss due to the shading effect of the woodlot or increased bird predation on the crop using the woodlot as shelter. In the *complex* space, there are so many interacting causes and effects that predictions of system behaviours are affected by a wide range of uncertainty. Decisions must be made without a clear or complete understanding of their potential consequences. For example, it may be less clear how the local residents view the creation of a woodlot; some will consider it a valuable landscape feature while others may consider it negatively as it blocks their view of the wider landscape or creates shade in their garden. In the *chaos* space, things happen beyond our experience and we cannot perceive any candidates for cause and effect. Our lack of understanding of the full causes and ramifications of climate change is an example of a chaotic space and currently this decision space is outside the scope of the TESS decision model.

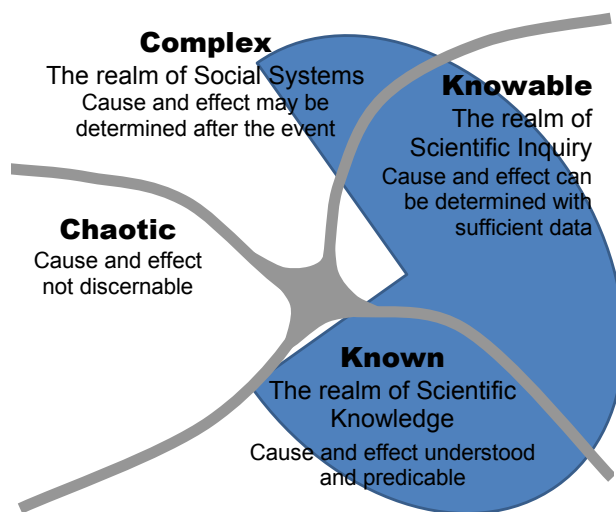


Figure 9. Cynefin model of decision space with area highlighted which the TESS decision support system is designed to operate.

According to French & Geldermann (2005), environmental decisions almost invariably fall into the complex or chaotic domains, particularly if they involve many stakeholders and hence need to address many social political issues: yet they note much work on environmental decision making seems to assume a known and knowable context. It is important for the user of the TESS core decision model to understand the level of certainty in the output provided by the core decision model.

Sources of Knowledge

The three types of “knowns” famously defined by Donald Rumsfeld are relevant for all decision support systems i.e. there *“are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know.”* These known knowns, known unknowns and unknown unknowns are a useful construct for considering the knowledge types necessary for land use decisions. It is envisaged that the TESS decision model will deliver data for the knowns, prompt the user to find data or at least consider the known unknowns, but cannot address the unknown unknowns initially (although it is envisaged that if users deposit knowledge in a central web-based database as proposed for the TESS decision support system the frequency of unknown unknowns will reduce).

Sources of known data

Data availability is a major concern for all decision support frameworks. We argue in favour of the solution adopted by the Intergovernmental Panel on Climate Change (IPCC) when faced by a similar challenge in relation to calculating the greenhouse gas emissions from countries. They provide high level emission factors available from a central database (Tier 1) but the user can use country specific numbers (Tier 2) or specific modelled output for their own defined area (Tier 3) (IPCC 2006).

A variety of publically available data sources related to land use commonly include biophysical, social and economic data. Three tiers of data can be identified along a spatial scale for example (i) Tier 1 international databases (e.g. FAO (<http://faostat.fao.org/>), World Resource Institute (<http://earthtrends.wri.org/>), (ii) Tier 2 regional databases (e.g. 27 countries of the European Union (<http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes>) or country specific (e.g. <http://www.scotland.gov.uk/Topics/Statistics>) and there are also more local data sets held by local administrative entities e.g. local authorities or National Park Authorities which may be considered analogous to Tier 2 while (iii) farm level data would equate to Tier 3 i.e. a single management unit.

As a need for these data becomes apparent to policy makers and local stakeholders, the TESS ethos would hope that they may become a free resource similar to that which arose in the academic community around R, the free open source software environment for statistical computing and graphics (<http://www.r-project.org/>), or Wikipedia, the free encyclopaedia that anyone can edit (<http://www.wikipedia.org/>). We consider a system like that currently operates for the R computer statistical software package, building with time to hold data relevant to all three tiers of data i.e. a series of list servers which are freely available and can be used to locate and deposit relevant data. We would encourage a similar system of referencing and acknowledgement which is currently accepted in the R community.

Issues of unknown data

We argue it is important that the user is prompted to consider a holistic ‘knowledgescape’, since there are likely to be elements which the user accepts are important but because s/he has no knowledge s/he may be inclined to ignore. In a robust decision support system the user should be prompted by the system which will bring the unknown elements to the user’s attention explicitly forcing them to either find data or make an expert judgement concerning the element.

The complexity of land use decision-making, discussed above, requires (i) a framework that captures the diversity of costs and benefits resulting from land use decisions, (ii) explicit recognition of conflicts that

may arise due to the decisions made about land use (Young *et al.* 2007; Niemelä *et al.* 2007; Henle *et al.* 2008), and (iii) the requirement for sustainable use of the environment at multiple scales. Ecosystem services provide such a framework for decision support systems (Chapter 3). Not only do ecosystem services include all the benefits accruing from the management of land but ecosystem services are now also at the heart of policy on land use. The publication of the Millennium Ecosystem Assessment (MA 2003) added considerably to the published literature (see Dick *et al.* 2011a). Ecosystem services are now firmly embedded in land use policy nationally and internationally, notably the Intergovernmental Platform on Biodiversity and Ecosystem Services (<http://www.ipbes.net/>); Larigauderie and Mooney 2010).

The list of ecosystem services used by the Environmental Change Network (ECN) would be a pragmatic starting point (Dick *et al.* 2011b) when creating the list of ecosystem structure/function/services which the system should consider. The ECN list is a mixture of quantified ecosystem services e.g. tonnes meat and presence/absence of a service e.g. provision of vegetables because in that study the authors could not quantify the service easily. It is envisaged that many of the items in the final list incorporated into the TESS decision support system will be a similar mix of continuous, discontinuous and binary data. In addition it is envisaged that many of the parameters in the final list will be irrelevant to the decision in hand and can therefore be set to 'neutral' and not require quantification in order for the decision model to operate.

The problem of unknown unknowns

The value of considering the trade-off between improved management arising from avoided costs (or windfalls) arising from the timely discovery of unknown unknowns was highlighted recently (Wintle *et al.* 2010). At the level of the individual, knowledge of unknown unknowns can only be amassed over time as new knowledge is gained. However, if a user community develops that is willing to share their knowledge then each time a problem arises due to an unknown unknown the community as a whole could learn.

Qualitative and quantitative approaches to decision models

Smith *et al.* (2011) recently reviewed the statistical tools available to inform decision making within an ecosystem service framework. They summarise eight types of tools available to aid decision making within an ecosystem service framework (Figure 10).

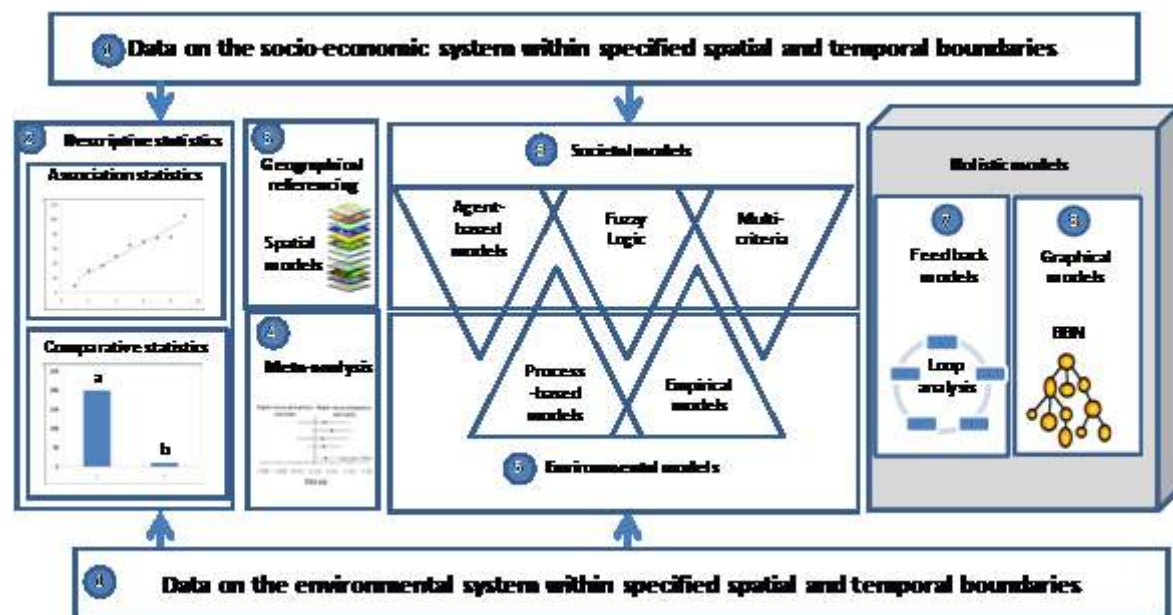


Figure 10. Range of statistical tools available to aid land-use decisions in 8 categories.

They recognise the need for both socio-economic and environmental data which in simple classical statistics is commonly analysed with comparative statistics e.g. t-test, Chi-square, analysis of variance etc or association statistical techniques e.g. regression. Many land use decisions are spatially specific and therefore spatial analysis techniques are relevant e.g. geographic information systems, remote sensing, spatial trends and hierarchical models. Meta-analysis is useful to bring together information from several sites or studies in a coherent way and to deliver a parsimonious but effective model for prediction

Combining an understanding of parts of a system leads to the development of more complex models. An example of a mainly qualitative approach to a decision support model is Fuzzy Cognitive Mapping (FCM) (Özesmi and Özesmi 2004; Yaman and Polat 2009). FCM considers the relationship between “concepts”, which can include different ecosystem services, the benefits that accrue from them and the factors that affect them.

In approaching the interface between environmental (often qualitative) and societal (often narrative) models, a basis is required which bridges the gaps and consolidates the available information. Bacon *et al.* (2002) looked at using belief networks in combination with multiple attribute value functions to assess land manager decisions. There have been developments since then and recently Johnson *et al.* (2010) presented an integrated Bayesian belief network to cover both the science and management challenges within a marine ecosystem. The positive benefit of a Bayesian approach is its comprehensiveness. It allows a coherent tracking of both the decision processes and the uncertainties that will be associated with each outcome while still providing flexibility within the structure and allowing expert opinion, process-based model structures and both quantitative and qualitative data to be incorporated. Consequently we favour a Bayesian belief network in decision support for land managers and policymakers.

Recommendations for the TESS decision model

The TESS decision support system should encompass a Bayesian belief network (BBN) as developed in the last two decades and applied to explore ecosystem management options (Bacon *et al.* 2002; Amstrup *et al.* 2008; Aalders 2008; Hunter *et al.* 2009; Johnson *et al.* 2010a,b). The graphical structure of BBNs is similar to that used by other decision tools where differing criteria may be used for optimisation, including neural networks and fuzzy logic, and so they link well between environmental and societal models. In addition BBNs accommodate knowledge of varying accuracy and precision which will be the case for many land use decisions. In order to make the Bayesian belief network manageable, only relevant elements should be included.

As the TESS decision model would be applicable at a range of spatial scales over a very wide range of ecosystems, a two part BBN with case specific sub-models is illustrated in Figure 11.

(i) the coloured nodes on the right hand-side of the graphic together form the generic elements;

(ii) the beige nodes are specific to the example used here i.e. planting a hedge on farm land.

The colours denote the social (pink), ecological (green) and economic (blue) knowledge elements and the colour coding scheme is repeated in the outputs but with a darker shade of colour. The ecosystem service element has been sub-divided into three components represented in this simple example as provisioning, regulating and cultural following the Millennium Assessment typology.

The beige nodes are case specific and while there will be much functional similarity in land use decision it is also recognised that there is a need to consider only elements appropriate to the decision in hand. The TESS decision support system is envisaged as a web-based community with access to a large amount of knowledge. This structure is not yet in place therefore we will illustrate the utility of the TESS BBN decision model with a simplified example. The TESS BBN decision model has been parameterised to illustrate the approach in the following section.

Two example runs of a BBN used the graphical output from BBN development software Netica (<http://www.norsys.com/>) to examine expected values of planting a hedge on good ground (Figure 11).

By increasing subsidy to 100% in Box B and from hardwood to conifer in Box F, the model predicts an improved chance of the probability of increased, neutral and degradation of the system from 24.8%, 26.1% and 40.0% to 31.1%, 26.0% and 42.9% respectively. While for the non-physical and physical well-being elements of the system the model predicted a modest probability of improvement (i.e. the probability of increased well-being rose from 42.6% to 44.1% and 45.7% to 47.0% for non-physical and physical well-being elements respectively); the major driver is the economic element with the BBN model predicting a probability of improvement in the system from 17.0% to 43.1%.

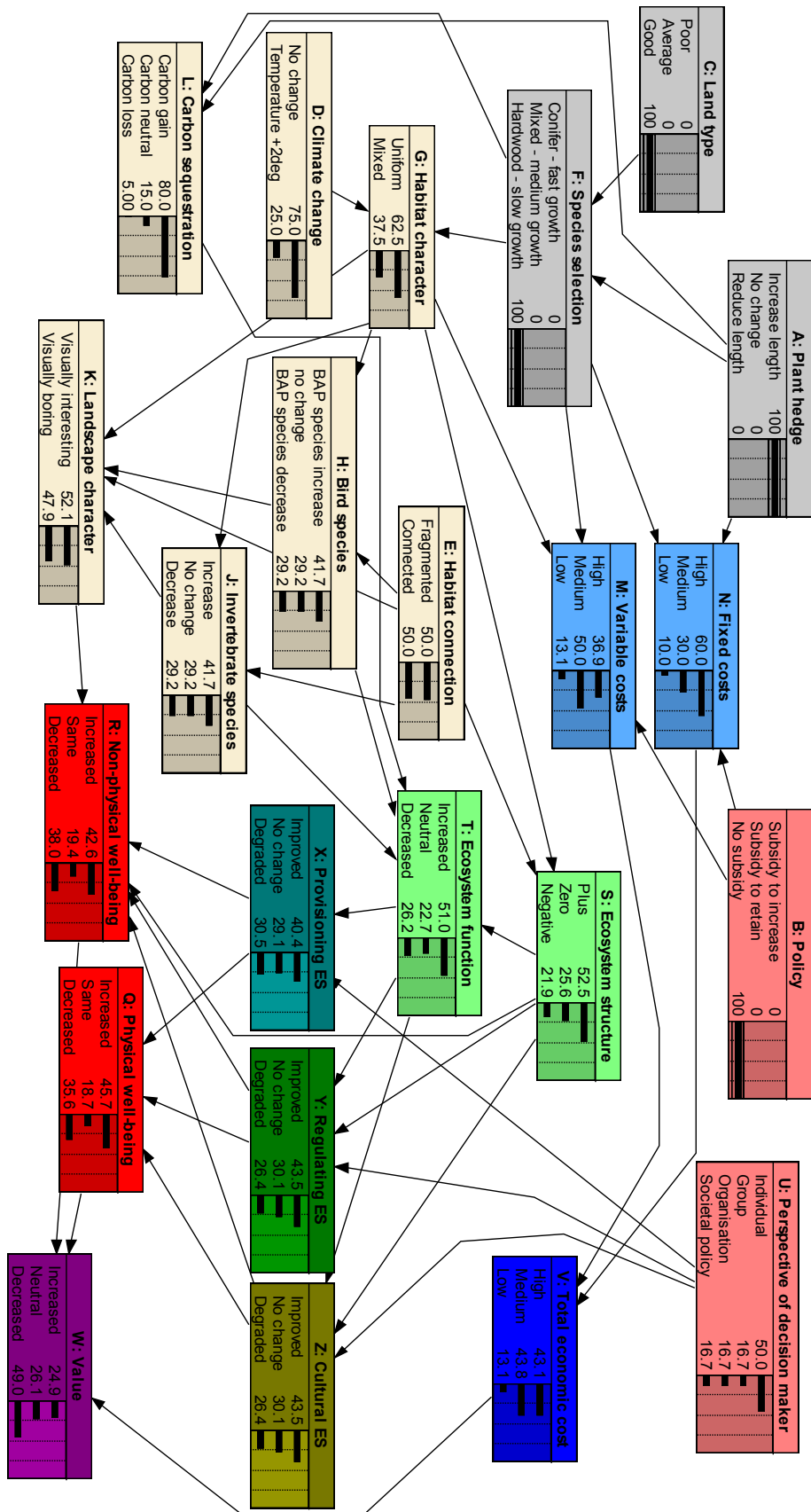


Figure 11. Example of the TESS Bayesian belief Network (BBN) decision model with the generic core BBN in colour and the specific case example of planting a hedge on farm land in beige with no subsidy.

This simplistic example illustrates one type of application of the BBN model i.e. when the user unequivocally determines the probability of a node e.g. that subsidy was or was not available. The BBN could also be utilised with a sub-model which predicted the probability that subsidy would be available for example by a simple rule based routine checking criteria such as whether or not the minimum area for the grant was fulfilled. Similarly the carbon gain in the example shown here is predicted to be higher when the conifer hedge is planted (probability of increased carbon gain raises from 80% with the hardwood planting to 90% with the faster growing, more easily established conifer planting). A sub-model could be introduced which utilised a processed based hedge growth model which if parameterised with local soil and weather variables could feed into the BBN a more accurate local estimate of carbon gain.

SYSTEM DESIGN TECHNOLOGY

Planning issues include appropriate governance for long-term support and funding, with the fundamental warning from NELUP and EISP that system-uptake would fail unless stakeholders who should use the system were identified in advance and consulted throughout. Therefore, identification and consultation started early in TESS for the socio-economic design aspects of this chapter. The other crucial aspects to be addressed by this model, which were less of an issue for earlier decision support systems like NELUP or EISP (Benson 1995; Culshaw et al. 2006), are handling liability for advice delivered to the general public, scaling from local to European levels, and integrating the different types of data and model across these scales.

Handling liability, scale and integration

The issue of liability for advice given will require users of the system to agree with conditions of use drafted by legal experts. There is now legal experience from a wide variety of internet service provision that includes decision support in other fields, and details would need to be based on the possible implications of advice to be given in the TESS.

In practical terms, liability can be addressed by attaching probabilities to predictions, as are now done for weather forecasts produced in text format. In some cases the probabilities will come straight from the statistical relationships used for modelling: e.g. removing V deer from area W gives an X% probability of no tree damage next year; there is a 90% probability that between R and S raptors of species T will be killed annually by wind-turbines at site U). In others, probabilities from a number of functions will be combined by Bayesian Network computations as explained in the previous section: e.g. area J of crop K should produce €L-M next year based on estimates of demand, supply and weather; probability of extinction of species O in region P will increase through habitat-loss to bio-fuels if subsidy €Q is continued. Of course, some outputs will be rule-based: e.g. subsidy on area C of biotope D is of €E); no building at this location (probability of permission to build is 0%). All these outputs can be expressed graphically in an intelligent GIS (iGIS), either by representing spatial probabilities as shades of colours or by pop-ups and text-bubbles, of course with filing of outputs as text if required. The pre-planning of text outputs from analysis scenarios also simplifies the production of information in a variety of languages.

Another critical need for a centre-local transaction system is the ability to scale up, incorporating raster-to-vector conversion for maps, nested grids for biodiversity records and summation of socio-economic data for appropriate indices. For a system conceived as an iGIS, the social, economic and ecological input data need to be spatially explicit and capable of integration across all levels of scale, from garden to Europe-wide. This can mean application as points (e.g. this tree trunk is at coordinates X,Y), lines (e.g. this hedge is a line from A,B to C,D) or as areas (e.g. there is Z g of carbon sequestered – mainly as a result of the tree in the 10 m cell X,Y).

Provided a variable can be made spatially-specific, it can in principle be turned into a set of values (e.g. € of farm income or kilograms of carbon) or other characteristics within an area at the required scale. This is a matter of spatial analysis and data aggregation and disaggregation, which is now handled routinely in

ecological modelling. Computing can be at the 1 m scale for community dynamics of ants, or at the 10 km scale for social attitudes and spending of local communities, or at the 100 km scale for large predator populations, though for fine details of interactions with prey one might want to work with probability of encounters in 100 m squares. All squares (or triangles giving hexagonal cells of equal central distance for colonisation studies) can be disaggregated to reduce scale or aggregated for higher scale, and the computations of life, death, encounter probability and economic value applied to the size of cell required.

Ecological, social and economic models too can be integrated, provided that relationships can be found between, for example, social attitudes and the density of problematic predators or economic value obtained from beneficial food species. Finally, the design will treat model algorithms in much the same way as other data, such that analyses can be run in different ways by selection from menus. The menus will have default settings that are used if there is no adjustment, but sophisticated users will be able to vary the analysis and conditions applied.

High Level Specifications

The TESS project team held workshops in Edinburgh and Brussels to specify high level requirements. This list is merely intended to provide a guide to the major issues regarding the system capabilities and not to specify tightly enough to be implemented by a developer.

1. The system shall be web based initially, but its architecture must be flexible enough that alternative frontends may be developed (applets, cloud, etc).
2. The system must be able to contain socio-environmental data (spatial and non-spatial data, map images) and models in various formats, for various locations and with varying degrees of confidentiality.
3. All data and models used in the system will be tagged by origin, as public or private and with other appropriate meta-data and will be held secure from unauthorized access.
4. The system shall also support standardized data-bases on private computers, on which the user can change data, mark it public or private, and use it with appropriate models in personal computers or on the system.
5. Public data will be acquired by the system, but may be changed by the system or originator [with keeping of a transaction history and version control].
6. There must be an appropriate backup and restoration system.
7. Models may be acquired by the system for its use on a public or commercial basis, after appropriate validation.
8. The user and the system must be able to make requests for data and models of third-party databases, providing payment for access where necessary.
9. The user must be able to compare data and models from different sources and otherwise check for validity.
10. The system must be able to verify and check data and models for integrity; format conversions will be treated similarly.
11. The system must be able to accept donations, subscriptions and payments on account for models and data.
12. The system must be able to present itself and interact with the user in many languages.
13. The user must be able to create a user account so that the system remembers the user's details (name, address, subscription and account details) at login; the system shall maintain a list of accounts in its central database.
14. The user must be able to search for data by various search methods - location, type, keyword, date and so on – and then view the results.
15. The user and system must be able to apply appropriate data conversions, models and uncertainty analysis in data and produce scenarios.

16. It must be possible for the user to provide feedback on the data and models and there must be a complaints mechanism.
17. There must be scope for documentation, Help and tutorials.
18. The system must be able to interact with large external databases (e.g. CORINE).
19. The system shall be scalable in terms of increasing number of users.

An Illustrative Domain Model

A domain model in software engineering describes the various entities, their attributes and interrelationships, plus the constraints that govern the integrity of the domain elements. The domain model derived from the TESS higher level requirements is shown in Figure 12.

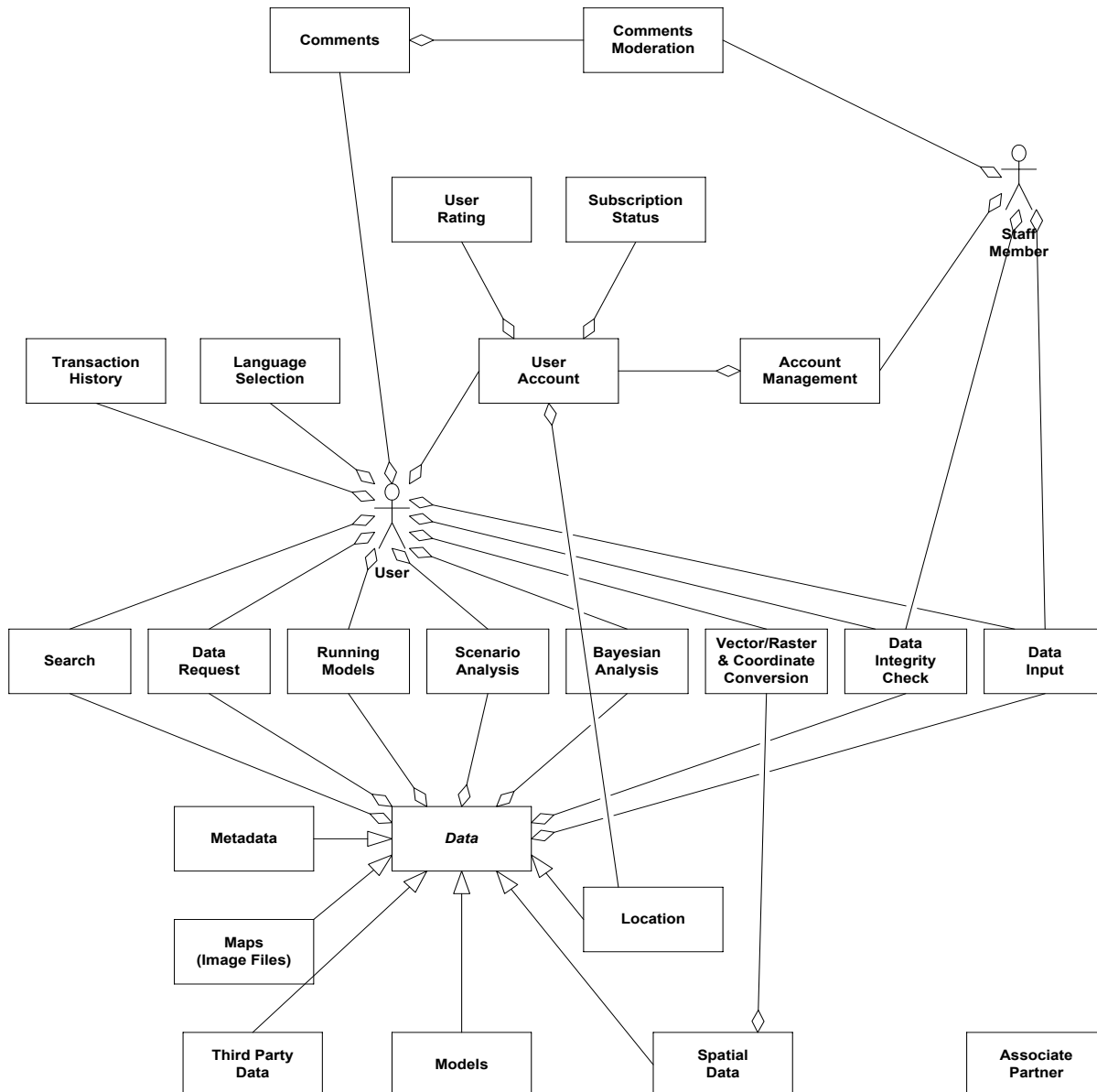


Figure 12. TESS system domain model

System deployment diagram

A UML system deployment diagram can be used to visualize the hardware of a system, the software that is installed on that precise hardware, plus the middleware used to connect the disparate machines to one another, as in Figure 13 for the TESS system.

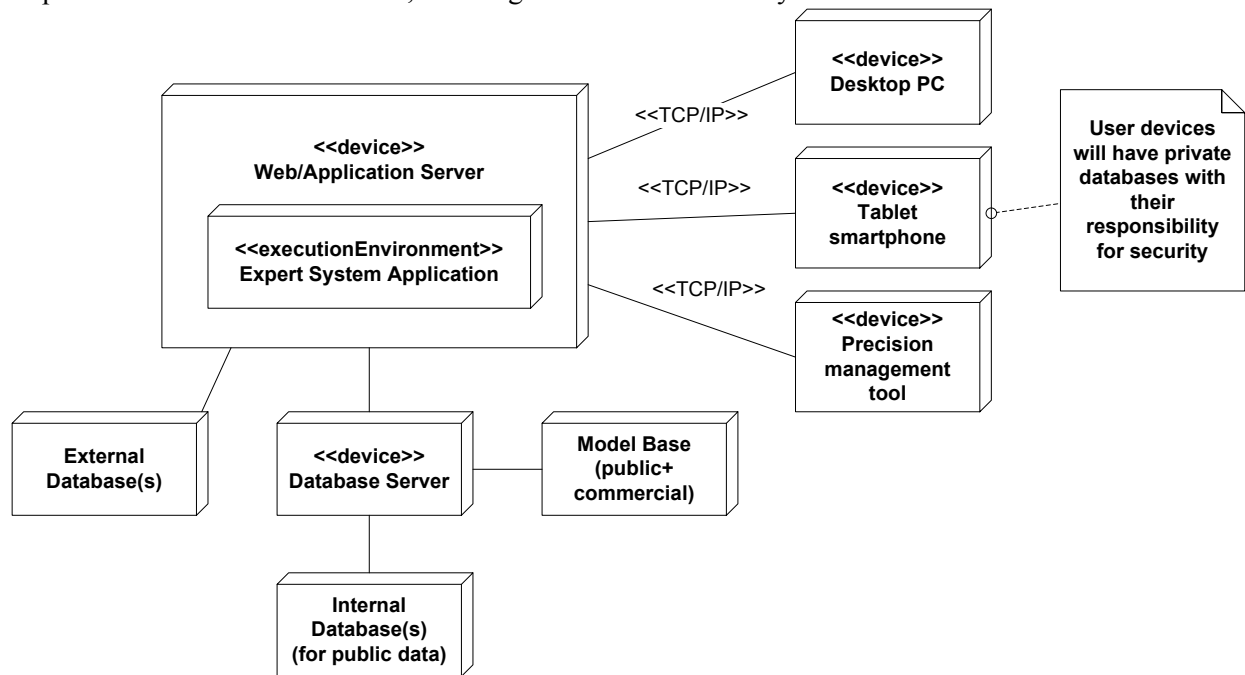


Figure 13. System deployment diagram

Use Cases

The use case view of a system captures its behavior as it appears to an outside user, by partitioning functionalities into transactions meaningful to actors. Use cases affect every facet of the system design; they capture what is required by the domain model and then show how these requirements are met. Figure 14 shows the relationships among TESS Use Cases, which are effectively the modules that will use the most appropriate coding technology at the time of system construction, and then be changed again as new technology becomes available. The novelty of the TESS design is not in creating code, but in including components not found in previous designs for environmental support, such as Use Cases 4-7 on handling quality and uncertainty of data and models, 15 on their ownership, 8+10+12 on translation and 13 on automated scenario analysis to reveal environmental problems unanticipated by the user. Use Cases 8-12 and 15 are already implemented on the continuation portal within which it is intended to build the system if adequate funding becomes available.

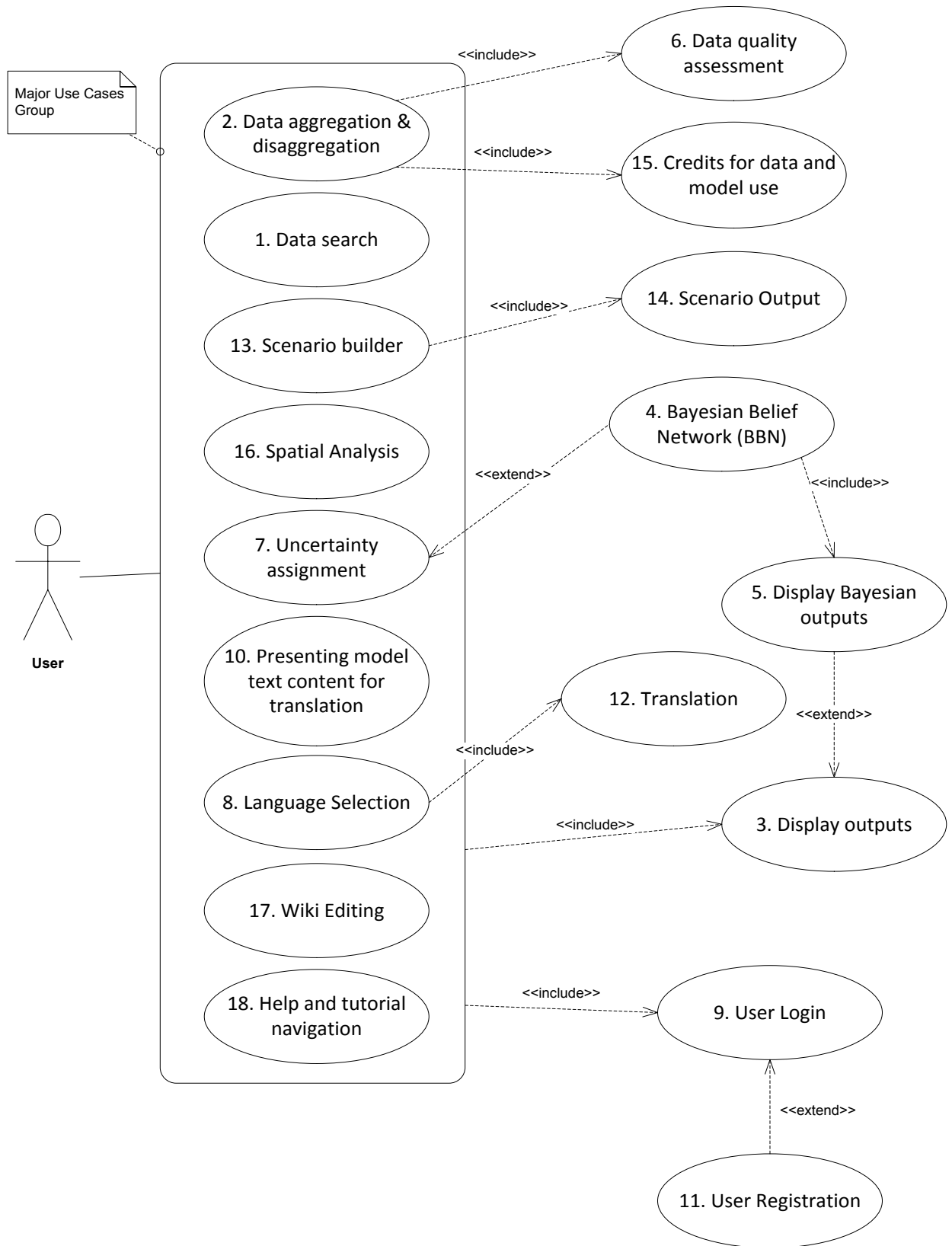


Figure 14. TESS system Use Cases. The numbers refer to comments in the preceding text.

SURVEY OF ORGANISATIONS

This survey was initiated because partners noted that government and individual stakeholders obtained much of their information from non-government organisations and consultants, and from publications and web-sites which would partly have been run by these non-governmental advisors (see Figures 5-7 in Chapter 7). With questions on SurveyMonkey in 24 European national languages, Country Coordinators contacted both national and more local stakeholder organisations, with help from their European umbrella organisations.

Survey Results

There were 50 usable responses from 22 countries, in 24 cases from organisations for hunting, 9 from organisations for cultivating land or water, 9 from organisations for nature watching or reserves, 4 for angling organisations and 3 for dog-training organisations. Responding organisations were internet-savvy, with only 10 of 50 lacking web-sites, and communication-savvy: 83% kept the media informed (e.g. with press releases), 76% used media champions and no less than 31% used social-networks. At least 60% of the 1.7 million members they represented were considered to access the internet for e-mail. Two of the 50 organisations named software that used predictive modelling to assist decision making. One cited software for linking spatial data with population viability analysis (<http://www.ramas.com/ramas.htm>), one an internal decision making system on subsidies and subsidy rates on forestry used by the Private Forest Centre in Estonia.

Two consecutive questions asked (i) “Which of the following services are on your web-site?” and, for the same list of 15 services, (ii) “How would you prioritise services for your members on an ideal site?” The resulting scores for presence and priorities were ranked, with the difference indicating the strength of aspiration for the service (Figure 15).

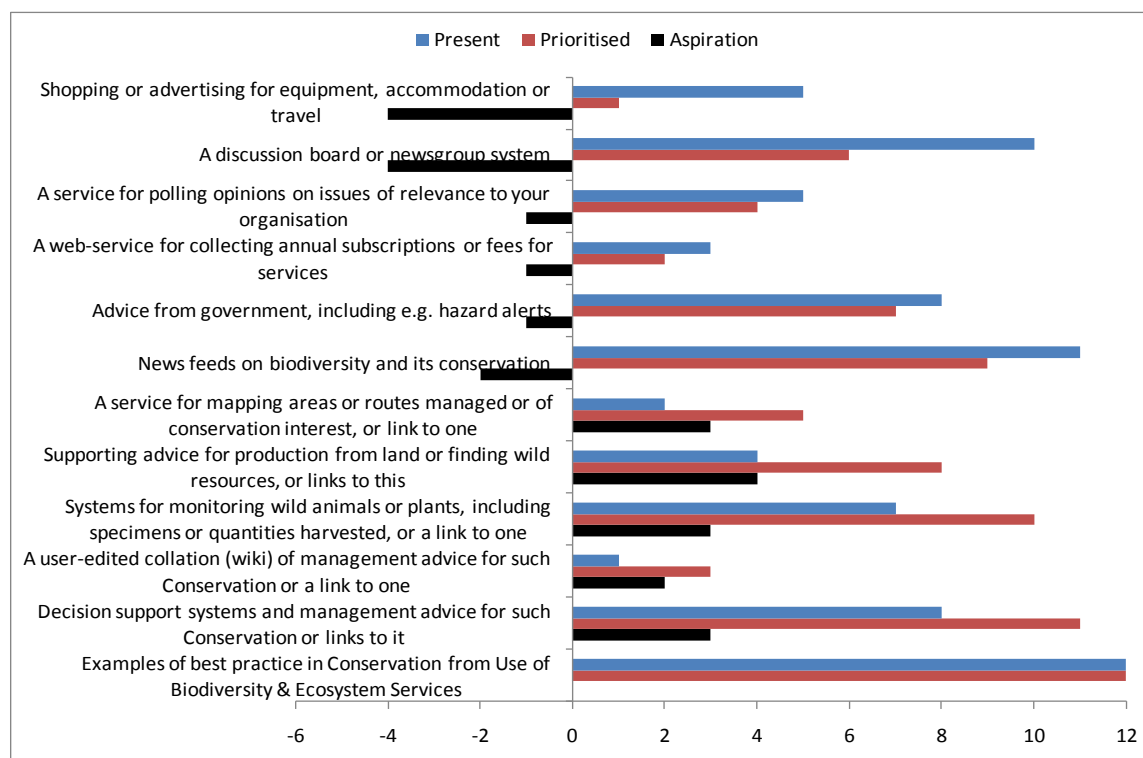


Figure 15. Web-services ranked by availability to organisations (dark) and as priorities for a site (paler). High requirement relative to availability (black) indicates services important in a new portal; aspiration was neutral (=0) for the popular “examples of best practice” at the bottom.

Thus, although news-feeds on conservation, discussion boards and e-shopping facilities were widely present, they were not strongly prioritised and thus rank as low aspirations in a portal. However, examples of best practise, links for decision support and monitoring systems were widely present and strongly prioritised, while advice on production and wild resources was highly desired but relatively unavailable; services for conservation mapping were also not available on sites but required by some organisations.

A further question asked about environmental information, in terms of “On which environmental topics would your members or clients most welcome information?” The options given were the same ecosystem service and biodiversity categories as in the previous surveys (Chapters 2-4, 6-9). Information on protected species and maps of ecologically relevant and designated areas were much the most strongly desired, by 70-72% of the 50 organisations. Information on ‘useful’ and harmful species (pests, disease-causing and economically useful ones) was also quite strongly required. Information on recreation, including tourism, was considered important, whereas information on soil and air quality, and on flood and fire risks, was in least demand.

SURVEY OF INDIVIDUALS

When surveying organisations, it was realised that priorities of individual stakeholder for web-services might differ substantially from those of organisations that represent them. For example, individuals might be much more interested in shopping and less in ways to collect their subscriptions. So it was decided to create a portal to survey individuals and to continue beyond TESS, perhaps as a focus for building a TESS knowledge exchange. A name was chosen to reflect the many stakeholder interests represented on the portal.

The Naturalliance Portal (www.naturalliance.eu)

As organisations expressed a strong desire for best-practise examples, these were provided as an attractant on the site, together with the downloadable TESS mapper, because mapping was relatively unavailable on existing sites. Links were provided to the most user-friendly models for decision support, to management advice on conservation, production and wild-resource use and to the most international monitoring systems. This provided 4 of the top 6 priority topics for an ideal site, and all with high of aspiration scores but relatively low availability on existing sites (see Figure 15).

The **Home-page** gives a choice of **21 languages** (eventually 27) for all following pages. An ‘**About**’ page explains what the portal does and why. Pages for **Topics** give examples of *best-practise* in conserving through use for communities and different stakeholders, with sub-pages linking to more information and *decision support* on each topic. Other portal sections are on **Species/ Habitats**, with the *mapping tool* designed for TESS and links to best off-site *monitoring* for species and other environmental topics, with a **Survey** page which is initially *polling* individuals to prioritise services for the future, and a **Register/Log-in** page (to which individual portal-visitors are directed after giving their opinion on services, to test *willingness to donate*).

The key to the portal is a back-office, on which designers, editors and translators have special privileges (Figure 16). This supported the role of TESS partners in translation for the survey, as shown above, and continuing translation beyond TESS through the network of ESUSG country coordinators. Although the editor has an auto-translate capability, translation by experts in the field is essential for ensuring that meanings of new ideas are conveyed fully and unambiguously, for example during surveys.

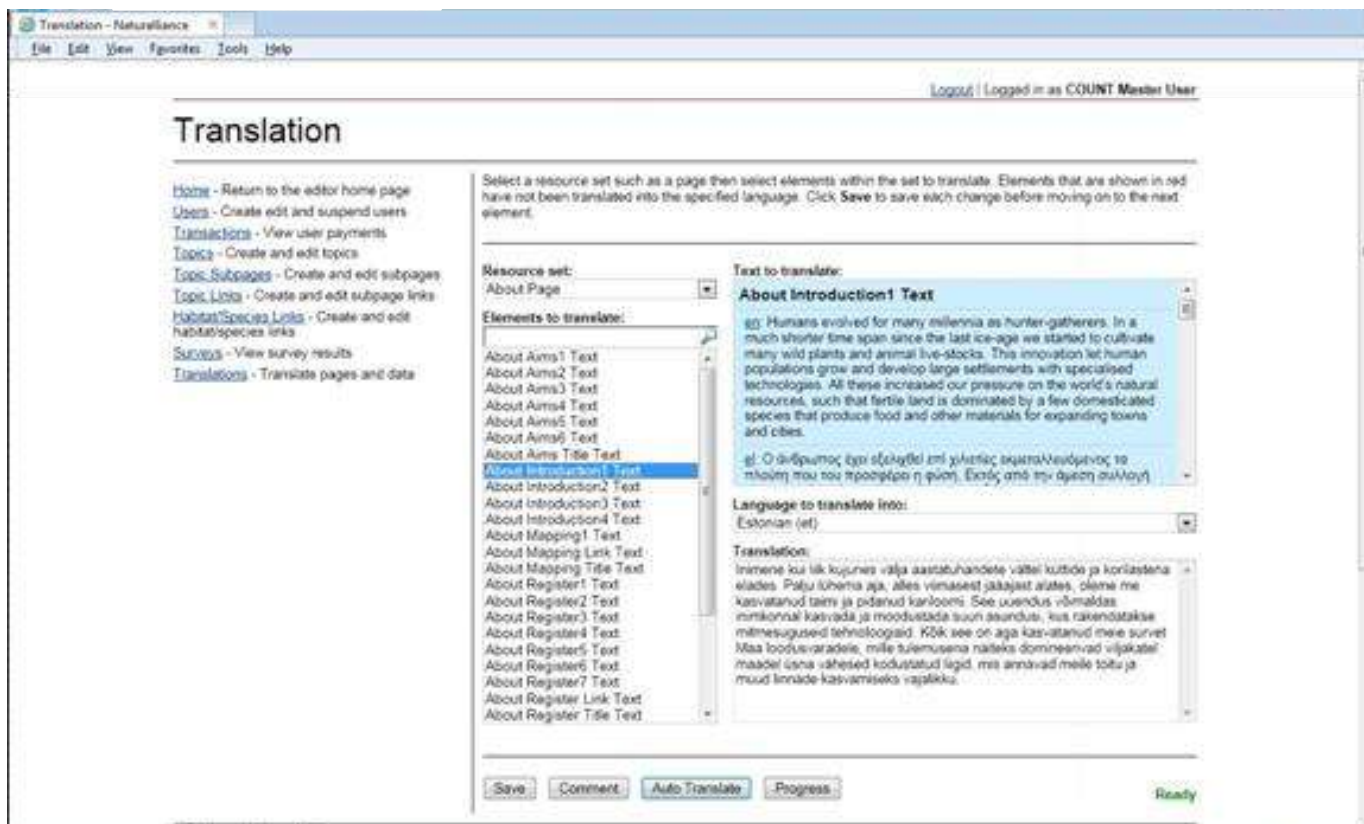


Figure 16. The Naturalliance back-office, showing translation in progress.

Results of the Survey of Individuals

From 219 unique users visiting the Naturalliance portal in July 2011, 57 individuals completed the survey. As half of the visitors listed science or higher government among their five main participatory reasons for interest in the site, and as a much lower percentage of these were rural inhabitants (54%) than among other respondents (80%), it was decided to analyse the data separately for scientists plus government officials and for other local beneficiaries of natural resources. There was also a high proportion who listed hunting or angling among their interests (56%), with rather fewer listing reserve management (39%) or farming or forestry (28%), so the survey was clearly strongly biased towards contacts of those working in the project. To minimise bias arising from including members of TESS partners who had completed the survey while being aware of findings from the previous survey of organisations, a further 8 individuals were excluded from analysis.

The ranked priorities for services on a web-portal were similar for individual respondents to those expressed in the previous survey of representatives from organisations. They most wanted examples of best practice in conservation through use of biodiversity and ecosystem services, with facilities for monitoring species and conservation news-feeds clearly the second and third most highly desired services (Figure 17). Decision-support was required too, though less than in the previous survey, whereas facilities for mapping were more strongly required. Local lay people were much more interested than scientists in discussion groups, with their organisations holding an intermediate preference.

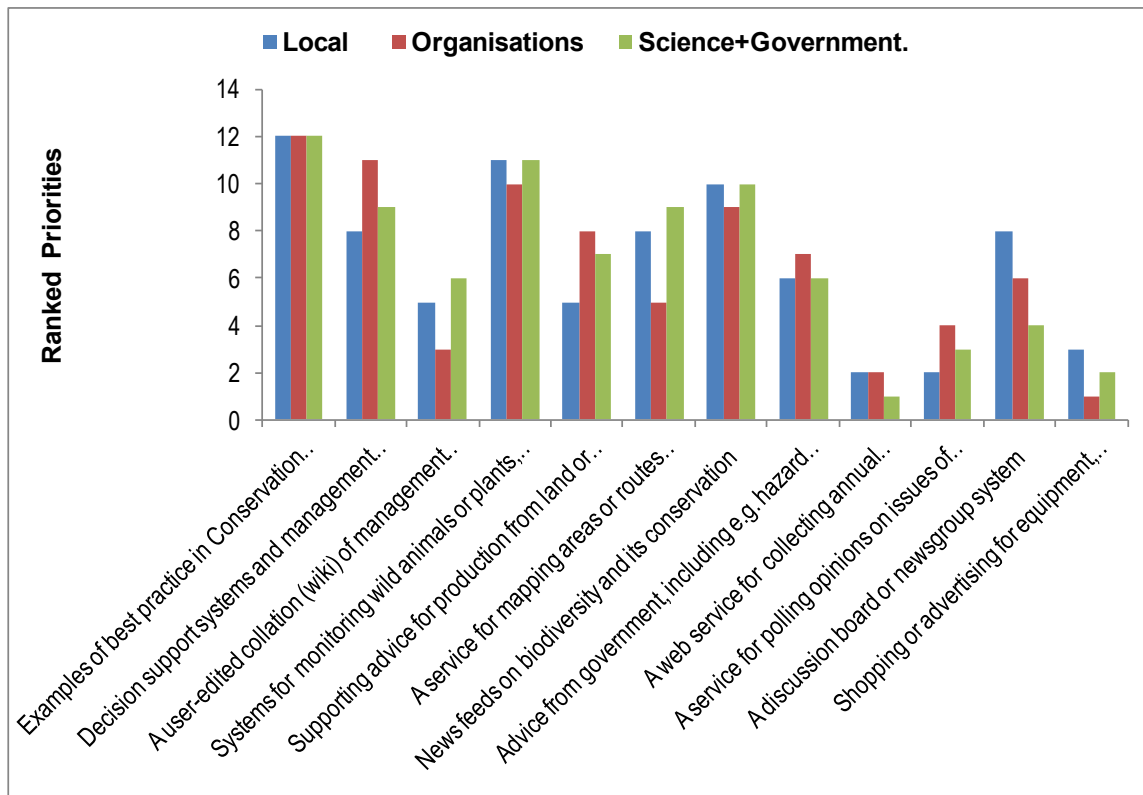


Figure 17. The priorities for web-services of individual local beneficiaries of wild resources, representatives of their organisations and of science or government.

The preferences for types of information were also quite similar to those in the previous survey, with information on protected species, invasive species or harmful species, and habitat maps, the clear first three choices in that order. However, there were two notable trends between categories of respondent. Among two of the three most popular types of information, on protected species and habitat maps, local lay people were slightly less interested than their organisations, which were in turn less interested than scientists plus government officials (Figure 18). Individuals, whether scientists, government or lay folk, tended to be more interested than organisations in information on species with socio-economic significance, whether harmful or beneficial, and in recreational access, but less interested in wildlife diseases than the organisations.

Although responses in this survey are self selected and probably biased to organisations with strong use of the internet, internet-use is likely to become the rule. Results may therefore merely be “future-biased”. Best-practise information is easy to provide on a site and as links to appropriate sites. It is also encouraging to record high demand for information and services on species, involving maps, monitoring and decision support, and on socio-economics of production and recreation, since it is in these areas that TESS has focussed. Interest in decision support may have been enhanced by the wording that introduced the survey, but strong interest in habitat maps and monitoring, which are essential citizen-science components for spatially-specific socio-ecological predictive modelling, would not be a result of such bias.

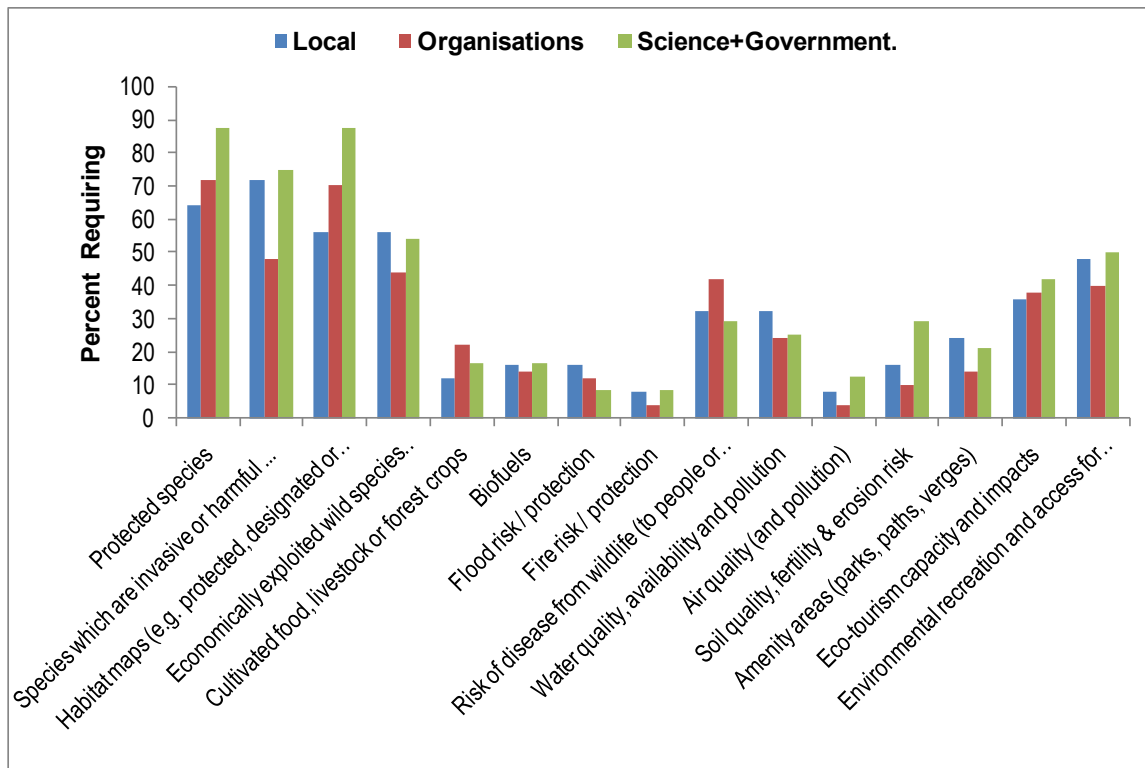


Figure 18. The priorities for web-information of individual local beneficiaries of wild resources, representatives of their organisations and science or government

MARKETING A TESS FOR THE LONG TERM

Local stakeholders need to use Europe's land and biodiversity sustainably (i.e. from CBD Article 2, "maintaining its potential to meet needs and aspirations of present and future generations"), while also embracing the many ways to restore biodiversity and other services from degraded ecosystems (Benayas et al. 2009). The potential for conservation and restoration of biodiversity is great, not only because 80% of European land is outside protected areas but also because there are large human resources using biodiversity. About 30 million Europeans are hunters and anglers, with recent increases in populations of most species they manage. In rural populations, 80 million are also gatherers of wild fruit, nuts, flowers or fuel, so even if gathering by town dwellers is less prevalent, there are probably at least 100 million European angling, hunting or gathering wild resources. Private spending on all biodiversity-dependent recreation, including gathering and watching wild species, is similar to the CAP budget. If encouraged and guided effectively, how much conservation could an alliance of these people achieve?

A key to restoring biodiversity in Europe is to realise that wild resource beneficiaries, often seen as part of the *problem* for biodiversity, can also provide *solutions* through IUCN's recognition of sustainable use as a tool for conservation. Thus, **conservation through use of biodiversity** is a way to improve the conservation status of species or habitats through either consumptive or non-consumptive use.

However, conserving by using biodiversity is more complex than passing and enforcing protection laws. Extensive knowledge needs to be distributed, to help those who have already started to organise conservation management through hunting, angling, gathering and watching wild fauna and flora, and also to showcase their efforts as examples of best practise. People need to be engaged and motivated, for example to monitor and restore, not just to keep "hands off".

Marketing the TESS concept is a matter of engaging the huge human resource of farmers, foresters, gardeners, hunters, anglers, gatherers, those who manage reserve or land access activities, and their many advisory organizations and consultants.

The Naturalliance web-portal is a way to continue market research for TESS beyond the end of the project, with the hope of raising funds to implement the services that users request. In accordance with the conditions for trust and durability recognised previously, the management to achieve this vision is being implemented by organisations based in civic (voluntary non-profit), private and government sectors. The vision of the venture is **“to enlighten, encourage and empower local communities to support biodiversity restoration across Europe, through an internet system that unifies all available knowledge to guide decisions of benefit for biodiversity and livelihoods”**.

Legal Form and Management

Two civic and two private organisations are managing the non-profit (social) enterprise, based on a contract that transfers the portal software at cost from Anatrack Ltd to the Game and Wildlife Conservation Trust once costs of construction have been met. The European network of IUCN’s Sustainable Use and Livelihood Specialist Group is providing country coordinators and Tero Ltd is helping with attendance at meetings and plans for funding. The portal software was built without TESS funding, but partners provided the translation and analysis of results from TESS budgets. Alignment of the system with governmental activities at European level is subject to advice from the European Environment Agency, which offered support in the Brussels conference for the continuation of the TESS network and concepts. An advisory group involves three other organisations at European level which represent stakeholder interests, with two more at global level as observers.

If growth justifies, Naturalliance could eventually become a foundation with advisory organisations as a board of trustees for steering long-term development. Trust-building would benefit from cooperation of diverse organisations representing those benefiting from wild resources, also in committees for guidance of relevant content nationally and of application locally. Care would be needed concerning the country for incorporation of a Foundation, both in terms of constitutional constraints, annual reporting requirements and taxation, and noting that such aspects may alter when governments change.

Funding

The challenge is to create an information portal which starts a self-funding process for building really effective decision support. Before a TESS inference engine is built, the aim is to register a base of contributors interested in conservation through use of biodiversity, attracting them with a variety of web-services, best practise examples and links to other information. We also intend to focus on encouraging community-based projects that are both fun and useful, building on the success of the TESS case studies. Such projects also have the potential to build not only local expertise and interest, but also trust between different interest groups, in local governments, and in the system. Motivation for community engagement was illustrated in the UK case study, where the local administration gave support in exchange for TESS running the 5-10-year survey and Parish Plan.

A number of sources were considered for high and low level funding, from public (government grants, municipality subscriptions), voluntary (large foundations, diffuse donations) and private (major corporations, individual subscriptions) sectors. With public funding currently compromised, diffuse private funding offers one approach, either for donation or for payment for services. It was decided to test willingness to pay “crowd-funding” donations during the launch

year of the portal, as there is no other website or portal aimed at bringing together the following properties of the Naturalliance portal:

- Conservation through use of biodiversity and ecosystem services;
- Working across all sectors and interests involved with land, water and biota;
- In a combination that involves recording of habitats and decision support;
- In the wider countryside and developed areas as well as protected areas;
- For government, science professionals and all citizens at every level;
- In all official European languages.

The challenge of getting enough income is one of (a) attracting enough visitors and of (b) getting them to pay. The key to making this model work is getting enough (i) support from organisations which encourage their members to visit the system, (ii) content that people want to pass to their contacts, also with (iii) possible free-advertising from sympathetic celebrities. In the event, visitor numbers have exceeded 7,000 and continue to rise steadily, with acceleration following launch events. So the site may meet criterion (a), with evidence both for (i) and (ii). However, with (small) contributions from less than one in a thousand visitors, crowd-funding is not adequate.

Development Planning

Three distinct phases were proposed for the development of the system (Table 4):

1. Design of the system to match expressed needs (Design)
2. Deployment of the system to the field and proof of concept (Development)
3. Start of full blown operations and achieving impact (Expansion)

Table 4. Development phases and targets for TESS implementation.

Design (2010-2011)	Development (2011-2012)	Expansion (2013 onward)
• Consult stakeholders	• Build brand recognition	• Constitute Foundation
• Define operational and business model	• Sign up members	• Broaden and deepen alliances on pan-European / global scales
• Secure IP rights	• Sign up commercial links	• Increase subscriptions / revenue
• Build management capacity and software	• Secure conditions for growth	• Build environmental Wiki capabilities
• Ally with conservation organizations and stakeholders	• Create a pan-European / global brand	• Build secure chassis for decision support engine
• Start operations	• Design Foundation	• Offer mobile & new services

Design targets (the first phase) have been achieved. We have designed a system that should meet stakeholder needs, as a result of consultations with user groups, work within the TESS project and further work planning a follow on project. A management group is established, strategic alliances created and a portal launched. However, sources of funding for further development and growth have yet to be secured.

CONCLUSIONS

A Transactional Environment Support System is seen as a way of improving information flows between policy-makers and stakeholders in order to benefit management of the environment at local level, and policy-making at high level to help that management. Knowledge leadership for adaptive management at local level benefits biodiversity and ecosystem services, so the system is designed for local adaptive management with knowledge leadership, as well as for adaptive governance and planning at European and national levels.

It is important for two other reasons to have a system for local managers of land and species, and not just for formal government environmental assessments (EAs, i.e. SEA+EIA). On one hand, local managers of land and species take decisions (which summate to change the environment) at a density >5 orders of magnitude greater than EAs. On the other hand, ca 100 million Europeans use wild biodiversity for recreation and spend >€60 Billion annually.

Surveys showed that local stakeholders want detailed information about species and habitats, but also revealed gaps in use of detailed map coverage, both for strategic assessments at high level and for biodiversity modelling to enable management at local level. Other serious gaps were the targeting of most EU projects at policymakers, while governments also underestimate numbers of people involved in biodiversity-based activities and have a lower requirement than local people for information on habitats. Yet the case studies showed that local people are capable and enthusiastic about mapping species and habitats.

Moreover, although more than 2000 models to assist decisions on biodiversity and ecosystem services had been built during the last two decades, they had not been made simple enough for use by those who actually manage land, water and biota nor generally been made available in languages other than English. Nevertheless, the wealth of models in databases shows a very considerable volume of knowledge in the scientific community that was considered sound enough for modelling; the few models usable at local level show that technology transfer to local stakeholders is practical, albeit perhaps initially through consultants and other advice services.

The necessary technology transfer, further modelling to fill gaps, and many other aspects of this would need engagement with many scientists, so they too (with government and local managers) are stakeholders in such a system. It must suit them too, as well as providing local knowledge for planners and central policymakers, and information that local people want in ways they can use.

The integration of information on biodiversity and related environmental matters from the local level into planning and land-use decisions generally uses maps and, in digital format, GIS. This applies for scientists and for land-use planning by government, but often also to the myriad daily decisions made informally by those who manage land and species. This, GIS is a lingua franca across all these groups, and even easy to provide across languages with translation of short words where symbols and intuition alone do not suffice. To enable local knowledge from individuals to be exchanged for decision support that is enabled by their mapping, the TESS proposal is for the decision support to be delivered in an intelligent multi-lingual GIS.

However, the success of building adequate coverage through information exchange will depend not only on good enough decision-support technology to make the exchange attractive but also on trust in handling private data and trust between different interests that need to work together to make best use of a support system across multi-owned and multi-use landscapes.

Technical considerations must be adequately addressed to ensure support of the environmental science community, which in turn can influence trust of government and private stakeholders. Features within the system must be transparent and auditable. Data tagging for accreditation, confidentiality and quality control are important, as are practical aspects, such as spatial scaling thresholds (e.g. 1 m through ground-based vector mapping for detail in heavily managed habitats,

5-10 m for vegetation blocks in large areas of semi-natural habitat). Uncertainty must be addressed throughout (e.g. with Bayesian networks). Finally, a system will only become effective for application at a broad geographic level, in GEOSS and GMES, if it becomes comprehensive in scope; this requires standardisation in cooperation with European authorities.

Becoming comprehensive will depend on adoption by the vast majority of stakeholders, which is also most likely if there is trust in the system operating equitably. For this reason, construction and operation should be a non-profit operation, in which all funding is used to improve the system. For durability, system ownership should be constituted in a way that precludes transfer into commercial hands at a later stage in development. The system should be able to handle commerce, including data and services as appropriate to ensure that it is effective, but should remain in charitable ownership as a trust or foundation, albeit with enough input from government and commercial sectors to encourage reputable and efficient operation.

In view of all these considerations, the socio-economic support-base for the system is proposed to be based in the civic (non-profit) sector, with guidance and support where practical from state and private sectors. Thus in the Naturalliance portal, the IUCN's Sustainable Use and Livelihood Specialist Group provides a network which is indispensable for expert translation and linking with local communities and managers of wild resources on land and in water, aided by SME Tero Ltd, while Game and Wildlife Conservation Trust controls finances and software, aided by SME Anatrack Ltd. From the state sector, European Environment Agency is giving support and is the potential link via EIONET to the Biodiversity Information System for Europe, as a basis for providing information to support policy decision-making at high level, and via Eye-on-Earth to provide seamless access for users to data collated at national and European level.

In theory, the very large numbers of local stakeholders across Europe mean that funding an internet-based system could be possible by summing small individual contributions. However, portal tests of willingness to pay suggest that crowd-funding is not practical until the system has enough decision support and other capabilities to be useful for individual stakeholders. Will governments or philanthropists appreciate that providing information to benefit local recreation and livelihoods, in exchange for data required at higher levels for environmental assessments, could also encourage local people to maintain and restore biodiversity and ecosystem services?

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KEY TERMS

Keywords

Adaptive Management, Bayesian Logic, Citizen Science, Domain Model, Data Quality, Habitat Mapping, Local Digital Enablement, Market Research, Species Monitoring, Technology Transfer