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Design of a data-driven environmental decision support system and testing of stakeholder data-collection

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ABSTRACT

The aims of this paper are to present the requirements and top level design of a decision support system that facilitates the exchange of environmental information between local level and higher levels of government, as well as to assess the possibility to include the local individual in the decision making process. The design of a tool for data collection and exchange of available data also aims to predict impacts of small-scale locally oriented actions by the local administration and residents on incomes and biodiversity, monitor results of the decisions that follow such prediction and inform central policy assessors to enable appropriate tuning of regulatory and fiscal incentives. The potential of data gathering for use in a DSS was tested by case studies across Europe. The main challenges for implementing effective environmental decision support are now more socio-economic than technical, requiring also a more local-orientated attitude of researchers and government.

1. Decision support systems background and concepts

Decision Support Systems (DSSs) are computerized systems which are based on two main pillars. Information Systems Science contributes to the planning and the application of DSSs with the supply of the necessary tools, materials and software, while the Sciences of Operational Research and Management provide the general theoretical frameworks for the analysis of various decisions. Other disciplines are also used to various extents in DSSs, including Systems Science, Artificial Intelligence, Cognitive Science and Psychology (Eom, 2008). Thus, modern DSSs are truly interdisciplinary. Indeed, Alter (2004) correctly states that contemporary DSS has developed into an umbrella term spanning a broad range of systems and functional support capabilities.

Arnott and Pervan (2008) analyze in depth the academic field of decision support systems in an exhaustive literature review; Holsapple and Whinston (1996) and Holsapple (2008) provide the basic structure of a DSS, while Manos et al. (2010a) presented a simpler, yet more concise and model-driven description of a DSS architecture. Liu et al. (2010) review the current research efforts with regard to integrated DSS and Power (2001, 2008) identifies five generic DSS types, as follows: model-driven DSS, data-driven DSS, knowledge-driven DSS, document-driven DSS and communications-driven DSS. According to this scheme, model-driven DSSs emphasize access to (and manipulation of) deterministic, optimization and/or simulation models and use limited amounts of data, which differentiates them from the data-driven DSSs that are capable of utilizing huge data warehouses. A project to develop the top level design for a Transactional Environmental Support System (TESS, www.tess-project.eu) was funded under the European Commission's 7th Framework Programme (FP7), as a system to synthesize mainly the first two of these DSS categories, using deterministic, stochastic and simulation models in various risk analysis scenarios that may also require large sets of geo-spatial data. The project ran from 2008 to 2011 (Kenward et al., 2013a).

DSSs often attempt to offer solutions in modern managerial environments which are full of redundant and complex information, in which rapidly evolving situations engage a number of individuals in the decision making process – very often on an international level. In these circumstances, DSSs projects have been known to fail (Arnott and Dodson, 2008), even at the stage of requirements analysis and initial development. That is why, especially in ambitious and complex projects like TESS, which need to involve state of the art web technologies (Bhargava et al., 2007; Zahedi et al., 2008), careful planning is an essential prerequisite, especially in order to check the feasibility of the system design and to ensure that the final users will actually use and promote it.

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Although technology for environmental DSS in both rural (Benson, 1995) and urban (Culshaw et al., 2006) conditions is long-established, a major lesson from these previous projects was the need to build a system that fits the requirements of users, by working with them throughout the design process.

2. Current status of environmental research in the EU

Topics like sustainable development, farm regional planning, climate change, waste management, food supply chain management, environmental protection and biodiversity conservation plus a number of other relevant issues are becoming major focal points of international research. All are interconnected; a major imbalance in one tends to affect the others and most can benefit from adaptive management. For both these reasons, a critical factor stressed by the Environmental European Agency report (Schutyser and Condé, 2009) is that continually updated datasets are needed. With our entire economy underpinned by ecosystem services, and biodiversity an important component in the ability of the ecosystems to deliver much needed services, how will appropriate datasets be obtained and updated at a regular basis? Who will fulfill the task and with what funds?

The Natura 2000 network of protected areas is a cornerstone of nature conservation policy in the European Union, covering many areas that are being enlarged through updates and expansion of EU political borders (Maiorano et al., 2007). In addition, directives for Environmental Impact Assessment (EIA), complemented by Strategic Environmental Assessment (SEA) have been defined and introduced by the EU as a requisite for projects and programmes having a significant effect on the environment. But biodiversity at local level is still declining at alarming rates across Europe (e.g. Thomas et al., 2004), despite measures like the growth in number of nationally designated protected areas in 39 European countries (Schutyser and Condé, 2009). The European target of halting the loss of biodiversity by 2010 has slipped away (Dimas, 2009) and moved a decade ahead, to 2020 (EU COM, 2011). In many circumstances, a regulatory framework is simply not enough (Manou and Papathanasiou, 2009) because a myriad small and locally based land-use decisions outside protected areas summate to change the environment. The resulting habitat degradation and loss is often not immediately perceivable, as Kuussaari et al. (2009) explain with the notion of 'extinction debt'. DSS design in TESS was aimed specifically at these small and locally based decisions.

The EU has funded much environmental research related to TESS, including a project on Governance and Ecosystem Management for the CONservation of BIOdiversity (www.gemconbio.eu, Manos and Papathanasiou, 2008) that lay foundations for the TESS project. GEMCONBIO brought together 12 partners from Greece, Sweden, UK, Germany, Belgium, Hungary, Romania, Iran, Indonesia, and Bolivia during 2006–2008 to explore the interactions of governance processes and institutions with sustainable development objectives and conservation of biodiversity across more than 30 thematic and geographic case studies. A worrying finding was that where biodiversity diminishes, local people may to lose interest in the natural environment, as shown by fewer people engaging in wildlife-related activities in the most urbanized parts of Europe (Kenward and Sharp, 2008). However, the strongest positive associations with conservation and sustainable use of biodiversity were for knowledge leadership and adaptive management (Kenward et al., 2011), which are quintessential characteristics of a DSS.

Other EU-funded projects relevant to data collection for biodiversity policy implementation – and therefore also directly relevant to the TESS – are ALARM, SCALES and EU BON. ALARM (Assessing LArge scale Risks for biodiversity with tested Methods, www.alarmproject.net), aimed *inter alia* to establish socio-economic risk indicators related to the drivers of biodiversity pressures as a tool to support long-term mitigation policies. The SCALES project (Securing the Conservation of biodiversity across Administrative Levels and spatial, temporal, and Ecological Scales, www.scales-project.net) has as a general objective to provide the most appropriate assessment tools and policy instruments to foster the capacity for biodiversity conservation across spatial and temporal scales and to disseminate them to a wide range of users, while EU BON (European Biodiversity Observation Network, www.eubon.eu) focuses on the delivery of near-real-time relevant data, both from on-ground observation and remote sensing, to the various stakeholders and end users ranging from local to global levels. A relevant COST (European Cooperation in Science and Technology, www.cost.eu) action was also launched in 2011, called HarmBio (Harmonizing global Biodiversity modeling, www.harmbio.eu), aiming to harmonize current biodiversity models and datasets in order to improve the reliability of future projections of biodiversity change (e.g. under various policy options which may be used to assist environmental decision making). The EEA (European Environmental Agency, www.eea.europa.eu) has launched the BISE (Biodiversity Information System for Europe, http://biodiversity.europa.eu) initiative for bringing together biodiversity datasets (albeit without analytic capabilities) and the Eye on Earth system (www.eyeonearth.org) that focuses on GIS data. On a global scale UNEP (United Nations Environment Programme) is working in parallel with the EU initiatives on the Global Environment Outlook, (GEO, www.unep.org/geo) and The Economics of Ecosystems and Biodiversity (www.teebweb.org).

3. Environmental decision making

De Marchi et al. (2012) provide a survey of formal methods available to help policy makers improve their decisions, while Moran et al. (2006) have worked in the analysis, implementation and assessment of public policies. Tsoukias et al. (2013) suggest a framework to support the use of analytics in the policy cycle – not only for environmental issues – and conceptualise it as "Policy Analytics". They correctly identify the need to use tangible and intangible public resources during the decision making process, the engagement of many diverse stakeholders with different and often conflicting interests, and the long time horizon needed for today's policy cycle. The role of stakeholders can often be complicated but their participation throughout will generally produce better decisions, as they are the ones who will bear the consequences of these same decisions (Voinov and Bousquet, 2010). Laniak et al. (2013) also introduce the concept of Integrated Environmental Modeling and using their own words this is 'inspired by modern environmental problems, decisions, and policies and enabled by transdisciplinary science and computer capabilities that allow the environment to be considered in a holistic way'.

It is in the above context that environmental decision makers need robust DSS tools; indeed, a resent advice paper prepared by the LERU biodiversity working group (League of European Research Universities, De Meester et al., 2010) recommends investing in interoperable databases using adopted standards as well as tools to use these data. Such DSSs combine environmental modeling techniques and IS technology in a fast-developing field; Jakeman et al. (2008), followed by Manos et al. (2010b) and Andreopoulou et al. (2011) all edited books on agricultural and other environmental decision support systems. Recently, McIntosh et al. (2011) identified the key research challenges for the development and adoption of Environmental DSSs and provided some recommendations for addressing them.

The development of an environmental DSS which uses high volumes of diverse data from multiple sources, must be considered in terms of complex systems (Sànchez-Marrè et al., 2008). Outcomes predicted by such DSS are liable to affect disadvantaged parts of society, such as the rural population, and to be influenced by many climatic demographic and socioeconomic variables which are difficult to predict. Addressing a variety of environmental problems requires cooperation between different groups, stakeholders, NGOs, policy makers and the local population. Trade-offs between system simplicity and scientifically concrete results may depend on quality of available data, which in turn depend on interrelated trust, confidentiality and uncertainty. Quality of data from citizen science or other local knowledge can be improved at input, for example by image recognition (Kumar et al., 2012) or during processing, for instance by application of fuzzy logic (Giordano and Liersch, 2012). Such systems require continuous evaluation by the end-user, for which the MIS (Management Information Systems) discipline provides tools, with perceived effectiveness by the end-user coming to focus especially in participatory planning (Inman et al., 2011).

4. The TESS project ambition and scope

TESS brought together 14 partners from 10 different European countries. Its aim was the requirements analysis and top level design of a decision support system to facilitate the integration of local knowledge into policy making, while at the same time guiding and encouraging local activities that restore and maintain biodiversity and ecosystem services. The vision was to enlighten, encourage and empower local communities to support biodiversity restoration across Europe, through an internet system that could unify all available knowledge to guide decisions for the benefit of biodiversity and livelihoods (Kenward et al., 2009). Considering that a core democratic maxim is that those affected by a decision should also participate directly in the decision making process (Smith, 1982), TESS sought to include the local individuals in the entire environmental policy cycle, and not only for data gathering activities as in previous participatory approaches (Jankowski, 2009; McCall, 2003; Elwood, 2008; Hessela et al., 2009; McCall and Dunn, 2012). TESS assessed also the possibility of models being applied to the available data for non experts, to improve their immediate decisions outside the higher level policy cycle.

In order to do that, TESS first listed and analyzed government information requirements at national and intermediate levels (Sharp et al., 2013), identified local information needs (Hodder et al., 2013) and quantified flows between sources and recipients of knowledge (Perrella et al., 2013). The project then developed a database of environmental models suitable for bio-socio-economic predictions (Ivask et al., 2013), and analyzed for gaps between the current supply of models and the forecasting required. From about 2400 models in the database, 198 were suitable for use by scientists at fine scale (field, pond, garden), but only ten of these were suitable for use by untrained stakeholders and only four could be considered easy for them to use (Kenward et al., 2013b). Of the ten locally-usable model-based routines, eight operated in English, one also in French and two in Hungarian. This created substantial deficiencies in documentation as a further factor hindering wide use of models.

Beyond the analysis of information supply and demand, TESS also investigated governance effects that might benefit from a comprehensive DSS, and hence motivate its development. A survey of national government and local practices, in 26 of the 27 EU member states plus Norway, Switzerland, Turkey and Ukraine (Ewald et al., 2013), identified factors associated with effective application of formal environmental assessments (EIA + SEA), together with priority areas for internet-based decision support and local monitoring to benefit livelihoods and biodiversity (Beja et al., 2013). Most of the factors which associated with prevalence of assessments, which in turn associated with low rates of urban sprawl, were attitudes, consultation and participation in activities assessed at local level.

As other EU research projects were focusing on recommendations for high-level policy, TESS focused its final stages on a top level system design for DSS delivery at local level, and on case studies to test what local knowledge could be supplied in exchange. We hypothesized that the system should be built to handle spatial data, partly because a Pan-European survey found about half the states to be digitally enabled for GIS in local authorities (Kenward et al., 2013c), with maps also used routinely for land-management by a diversity of interests. A crucial consideration is that maps at local level aggregate and scale up to much wider coverage. Studies of participatory GIS that can be applied to public decisions indicate that the proportion of people willing to participate gets smaller as the spatial scale of decision increases from local to the regional and national level (Kingston et al., 2000); this too made it appropriate for TESS to work at local level.

Following the case studies presented in the next section, the TESS team organized a number of workshops to assess the lessons learned and produce the top level design of the envisaged system. The higher level requirements of the system are shown in Fig. 1a and b according to the SysML (Systems Modeling Language, http://www.omgsysml.org/), requirements diagram standards. Each requirement is represented by a box with a unique id and a short text providing a concise description; some boxes include a "refinedBy" section that contains the associations of these requirements with the use cases produced by TESS (Kenward et al., 2013b). The system design is internet based, accessing large external public databases plus smaller ones held privately by individuals, with a configuration approximating Fig. 2. The TESS project revealed that the environmental modeling and database community is largely fragmented, disparate and uncoordinated, with diverse (input/output) metrics and without any effective demand in the model creation phase for compatibility among models. Therefore, agreement on environmental indicators and model metrics plus evaluation criteria will be needed for harmonizing the models before entering them in the model base. While models and toolkits remain accessible as separate modules, it will probably be necessary to distinguish models and toolkits according to their complexity, such that non-experts can be encouraged initially to interface with the less complicated ones. All models in such a system must be accompanied with adequate and easily comprehended documentation, with as much as possible for non expert users. A comprehensive system would become very large and require techniques like managed evolution (Murer et al., 2011). However, it could be started by merging models as a series of toolkits in separate sectors, such as farming and forestry (Piirimäe, 2011).

TESS differs substantially from other initiatives such as IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services, http://ipbes.net/). IPBES is an interface between the scientific community and policy makers that aims to build capacity for and strengthen the use of science in policy making at high level, while TESS favors a bottom-up approach; it aims to mobilize local human resources, by producing a system capable of handling huge amounts of diverse information in a coherent and easy way for the local farmer, gardener, hunter, etc. This is a system to motivate conservation of biodiversity and ecosystem services, because it benefits land-managers financially (Ayoo, 2008) or culturally (e.g. for recreation), in effect providing payments for Ecosystem Services (Ferraro and Kiss, 2002) through private spending of money or time. Moreover, be self sustaining in the long run, the system needs to become attractive enough to users to gain subscriptions. In this context it also needs to motivate its users; researchers, administrators, managers or other local residents need to receive the credit for the data they provide and to get other data and feedback in return (Fig. 2).

5. TESS case studies analysis and results

In order to discover how hidden local knowledge could be brought to the surface, TESS partners assessed local capabilities and willingness to adopt new technologies. Could credible data from the local level be fed to the regional and national level, both for making policy across Europe and to help formal Environmental Assessments, like EIA and SEA to produce more robust results? Case studies of local communities tested whether volunteers (based on schools, NGOs, local community groups or individuals motivated by use of natural resources) could provide effective local monitoring that meets central policy requirements, and what could motivate them to do so.

The project partners were asked to choose a local community in their countries at the lowest level of government (LAU2) and then to organize a team of local residents as volunteer 'helpers'. The project teams offered training, guidance, equipment and collation of the results, but field work was done by the helpers only. The aims of each case study were to test how best to meet a local decision support need in exchange for local monitoring that could meet central policy requirements. Projects typically required mapping of ecological information, for combination with socio-economic information. Helpers therefore worked in each case on a socioeconomic project and a mapping project (except in the German case, which had only a mapping project). However, in order to assess motivations, case studies also assessed other relevant local factors,

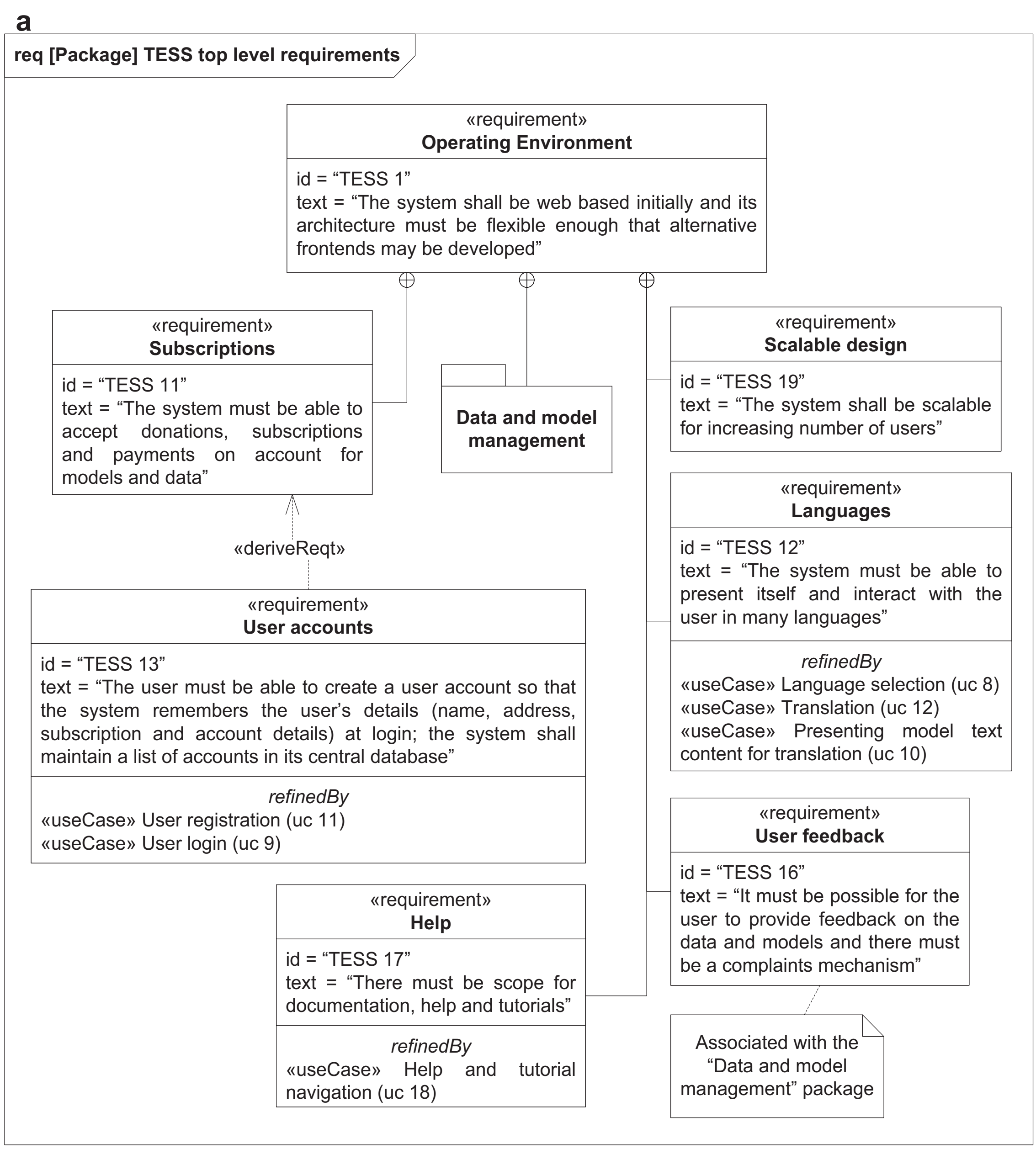

Fig. 1. a and b. SysML requirements diagram standards for a TESS; each requirement is represented by a box with a unique id and a concise text description; a "refinedBy" section in some boxes includes the associations with TESS use cases (Kenward et al., 2013b).

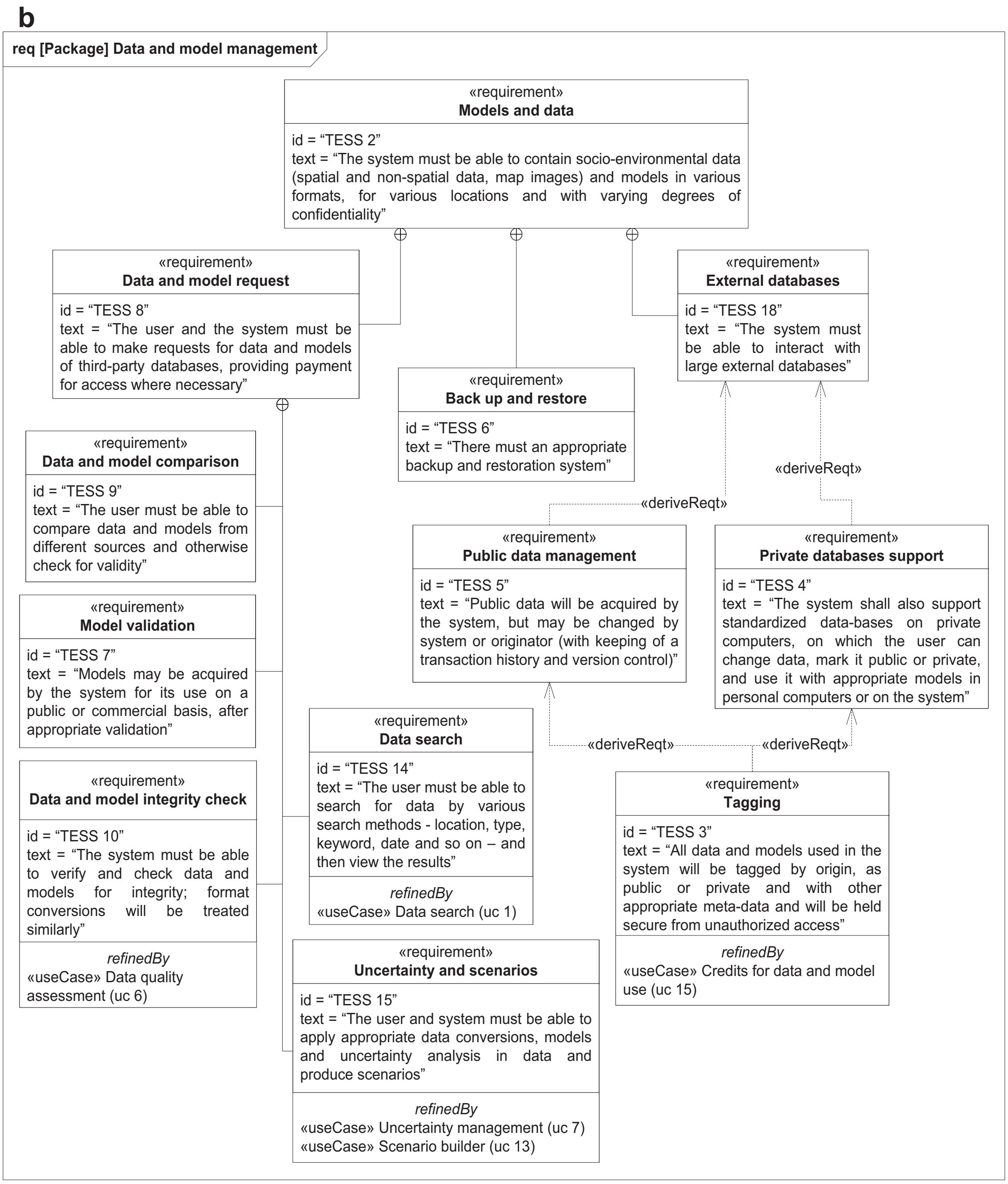

Fig. 1. (*continued*).

including participation in activities dependent on land, water and biodiversity and attitudes to environmental costs and benefits (Manou and Papathanasiou, 2013). In all, 10 case studies were conducted in 8 European countries (Table 1). Table 1 refers to activities like riding horses by tourists in the Greek case. This is an important source of income in the area, as there is a long lasting and ongoing effort to develop ecotourism in the area. There are various routes used for this activity, but there are no formal regulations applied for this and there have been some security concerns expressed by the locals as some of the routes used for riding horses overlap with routes used for hunting. Bearing this in mind, formalizing the routes used by the local riding horses' guides by mapping them is considered a necessity by many of the locals. In order to generate a diverse set of mapping activities, other case studies included mapping surplus vegetation at fishponds in Poland, wild rabbit density in Portugal, hares in Germany, wild fruits in Romania, deer and their habitats in the UK, land management generally in Turkey and cycling routes in Estonia and Hungary (Table 1).

5.1. Assessment of local information needs

The socioeconomic project aimed to assess the availability and adequacy of information from the local population and their awareness of local environmental issues. In each case there were a number of meetings involving the local community, and standard

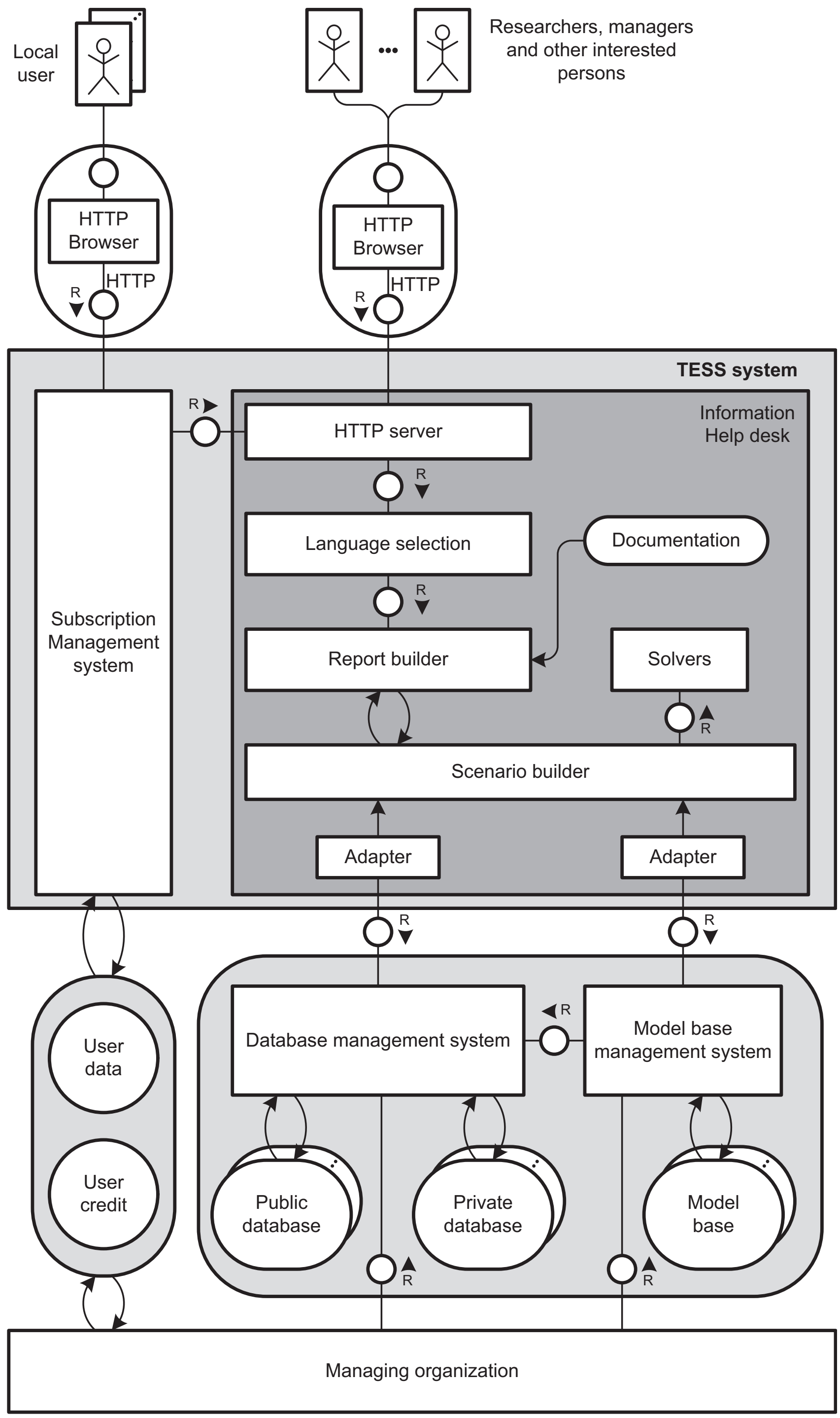

Fig. 2. TESS system configuration designed following the specification guidelines of the FMC (Fundamental Modeling Concepts, http://www.fmc-modeling.org).

questionnaires were distributed. For instance in the Greek case, based in the municipality of Kerkini, in the north part of the country just south of the border with Bulgaria, the socioeconomic part was titled "Exploring the development of new tourism activities in the Municipality of Kerkini by using the area's natural resources sustainably". The objectives, duration and stakeholders are described as an example in Box 1.

The questionnaire was developed through discussion among TESS partners, including a workshop, and with feedback from local communities in a variety of different landscapes. Table 2 shows the types of data collected on countryside activities and attitudes that were collected from local citizens. Local authorities too were surveyed for the case study areas, at the lowest level of local government (LAU2) and the level above (LAU1), where officials were asked to estimate the proportions of citizens that engaged in each activity and what their attitudes would be.

Other questions assessed the educational level of citizens (which scored 1 for attending school, 2 for attending university or technical college and 3 for a higher degree), their IT knowledge and capabilities (in terms of use of computers at home, at work, to

Table 1
TESS project local case studies.

Study area	Mapping: a. Species-Habitats b. Stakeholders	Socio-economic: a. Abstract b. Stakeholders
Municipality of Kerkini (Greece)	a. Riding horses routes, wild boar paths, walking and climbing paths b. Hotel owners' informal cluster, Riding Horses owners, Hunters' association	a. Development of tourism activities related to the area's biodiversity such as bird watching, herb collecting etc. b. Hotel owners' informal cluster, Riding Horses owners, Hunters' association, Womens' Association of Ano Poroia, fishermen, individual volunteers
Laulasmaa Landscape Protection area (Estonia)	a. Routes for recreational activities b. Bicyclists	a. To organize recreational activities to better fulfill the needs of walkers, joggers, bicyclists, skiers, anglers, etc. b. Local authorities, local NGOs, local residents
Bózsva (Hungary)	a. Mapping of cycle route paths / of the area of a flood b. Local residents	a. Building a new cycle route b. Mayor of Bózsva; Notary of Bózsva, Zemplén Bike Tourism Association (NGO); Happy Bike Ltd.; Coordination Center for Transport Development
Zator (Poland)	a. Mapping the overgrowth of fishpond with some emphasis addressed to flora protected species b. Locals	a. Active protection of habitats and species through the revitalization of fishponds in the Przyreb fishpond complex in the Zator district. b. Fisheries Research Station in Zator, Carp Valley Association, with its seat in Zator, Society for the Earth in Oswiecim, Ornithological Working Group of the Upper Vistula River Valley CZAPLON, District Management of Polish Hunting Association, Krakow
Southeastern Alentejo (Portugal)	a. Wild rabbit b. Local residents	a. Evaluate whether local people can incorporate work (paid or voluntary) in wild-rabbit monitoring and other regular monitoring programs in the Barranco's region, thus contributing to generate a new field of activity for locals b. Farmers, game keepers (representing hunters), land-owners, government environmental agency technicians, local administration elected officers, managers and technicians of local companies
Sfantu Gheorghe commune (Romania)	a. Sea-buckthorn fruit (*Hippophae rhamnoides*) & Sand Morning Glory (*Convolvulus persicus*) b. Schoolchildren	a. Identifying the exploitable wild resources within the area (fruit trees, medicinal plants, mushrooms) and developing local shops or supplying networks to sell the products b. Local stakeholders, tour-operators, associations
Egirdir lake, Isparta (Turkey)	a. Demonstration of land use in Kovada Lake National Park b. Local residents	a. The identification of priority habitats for conservation. Case study area has different habitats and land use types, therefore income of local people based areas near protected areas and its affect on that areas. b. Llocal stakeholders
Firtina Valley, Rize (Turkey)	a. Demonstration of land use in Çamlıhemşin district b. Local residents	a. The aim of the case study in Firtina Basin is to guide local NGOs and authorities in monitoring and management of land use. b. Local stakeholders
Frome Catchment (UK)	a. Deer and their habitats b. Local adventure scouts, local residents	a. Assess the linkages between human well-being and the benefits derived from ecosystem services as perceived by the local community and other stakeholders b. Environmental NGOs, government agencies and wider community
Municipality of Gehrden – Leveste (Germany)	a. European brown hare b. Hunters	-

access the internet and to buy goods on the internet) and the attitudes regarding protecting, maintaining or restoring wild species and/or habitats by those engaged in the countryside activities. In 7 countries the standard questionnaires was applied to 20–30 households in each case study area, selected by randomizing street names and numbers or from electoral rolls. There were 19–28 responses in 5 cases, but only 9–17 in the two Turkish areas. In the UK the local authority was motivated to participate by help with an Agenda 21 consultative survey of the whole Parish, which the TESS partner arranged and returned 335 questionnaire responses. Helpers in all cases were responsible for gathering the questionnaire data and they too were asked in a separate questionnaire to report their motivations for helping and their experience during the project activities.

Fig. 3 shows the perception, by respondents of the case studies questionnaires, of changes in the main occupations and other sources of income dependent on land, biodiversity or other ecosystem services in the last 20 years. In more than half the case study areas, agriculture was deemed to have declined, whereas nature-related tourism was considered to have increased greatly in almost all areas, with increase also in other recreational and conservation uses linked to nature-related tourism. Forestry, fishing and hunting were mainly deemed to have remained unchanged.

Increasing interest in recreational and conservation activities might motivate use of decision support software for optimizing use of ecosystem services. However, there was concern that the potential resources available through this increased interest was not being recognized by governments, whose subscriptions would be necessary to build and support a TESS. We therefore compared the mean participation in countryside activities that were registered by random citizens in case studies with the participation levels estimated by the two tiers of local government (Fig. 4).

Box 1
Greek case study socioeconomic project.

Objectives

Local people rely heavily on tourism for their income. The area welcomes tourists from all over the world especially for bird watching as well as horse riding, canoeing and other recreational activities. As local people tend to engage more and more in ecotourism activities to raise their income, it is very important to protect the area's biodiversity especially the endangered species like certain birds and the water buffalo along with the socio-economic benefits arising from those animals and plants.

The goal of this study was to address on one hand the need for welcoming more tourists and expanding tourism activities and on the other hand the need to preserve biodiversity. The project was to help local people to improve their livelihood by raising their income while preserving the area's biodiversity. They were to find ways to develop new recreational activities and products for tourists, such as cycling, herb collecting or even producing local wine. This required information on the species, habitats and location of resources, their numbers and use. We engaged the local community in gathering data for assessing the link between further development of tourism and conservation of biodiversity as well as direct and indirect acquired benefits. The main objective was to bring together the local community, local authorities and stakeholders with special interest in tourism activities in order for them to implement a network which would work for the benefit of the area's biodiversity while developing and expanding tourism.

The specific objectives were:

- To raise local awareness of the social and economic benefits of protecting biodiversity;
- To assess the economic value of the area's resources for each group of stakeholders;
- To help the locals to identify possible ways to develop new activities related to ecotourism;
- To help them attract new groups of tourists with special interests.

Duration

The study lasted for 6 months. The work included desk preparation by the AUTH (Aristotle University of Thessaloniki) team, such as translation of questionnaires and collecting data regarding the area's biodiversity, main economic activities and tourism. At first there was a preliminary meeting with the local stakeholders in order to identify the needs of the local community. Five informal meetings followed between members of the AUTH team and local community helpers in order to assist them both in the mapping project and in planning the socioeconomic one. These meetings also involved some training for the mapping project.

Finally, a workshop/meeting was held with the local community where the socioeconomic project was thoroughly discussed, focusing on the possibility of creating an informal network between the various stakeholders.

Stakeholders involved

- Hotel-owners
- Riding-horses owners
- Hunters
- Local authorities representatives
- Women's agricultural association
- Individual volunteers

Data collected

The data included first of all the TESS Questionnaires. It also regarded information on the species, habitats and location of resources, their numbers and use. In addition, information on hotels' room capacity, on tourists' preferred activities and/or needs was collected. These data may be further used in planning and developing cycling roads, hotel building etc. or published for tourists and attracting more visitors. The local stakeholders have in this way identified the exploitable resources of the area as well as the potential ways to use them for ecotourism and recreational activities.

Possible problems identified

The main problem at this point is the serious lack of IT education and training especially among the most productive ages of 40-something. Although it seemed that the local stakeholders were most willing to participate in the project, they found it difficult to follow. Younger generations (schoolchildren mostly) are more familiarized with computers and internet. Another problem identified is the mistrust between the locals; hotel-owners are very competitive with each other and reluctant to share information, while other professionals such as tavern-owners or fishermen are not always willing to cooperate as if development of the area will benefit only hotel-owners.

It must also be noted here that the Municipality of Kerkini goes through important administrative changes, as the Greek government applies the "Kallikratis Project" for uniting municipalities to decrease their costs. This process is about to be completed in the forthcoming months and local people are heavily concerned about the future of their municipality. Due to these administrative changes, it was very difficult to engage local authorities to the socioeconomic project, because there is a great confusion on the distribution of authorities right now. Moreover, local authorities are urging to keep their status and will not easily work on other issues for the moment. For all these reasons, it may be hard at this point for the locals to proceed with the project, as they need more IT training and more willingness to assist each other in this effort.

Best practice examples

The informal hotel-owners cluster may serve as a good example of the local efforts to develop ecotourism while protecting the area's biodiversity.

Future information needs

Several information needs have been identified which would benefit the implementation of the socioeconomic project if available. These are:

- Information on the numbers and types of species which could be published through internet in order to attract tourists with special interests
- Data on the incoming tourists, such as their country of origin, their special requests/interests, the preferred season of visiting etc.
- Information on new points of interest (walking and hunting paths, cycling paths etc.)
- Coordination among local hotel owners
- Coordination between other local citizens who benefit from tourism (eg. horse riding owners)
- Coordination with international partners

Participation varied considerably between different activities, with more than 50% of households engaging in exercise in the countryside, and in collecting fungi or plant materials (e.g. flowers, fruits, nuts), but less than 20% in hunting and riding horses. Participation also varied considerably between different case study areas for some activities. For example, 70–90% of the households were feeding and watching wildlife in four of the nine countries, compared with 30% or less in the other five. However, the most consistent differences were between the responses of individuals and the estimates of local administrators. Local authorities assessed a lower engagement in activities than recorded by citizens for all the countryside recreations. Hunting alone presented a relatively good match of results, probably due to the local authorities knowing the number of licensed firearms in their communities.

Perception by citizens of benefits from nature (average scores from questions in Table 2) correlated strongly with average education levels in the study area (Pearson correlation $r = +0.81$ with 7 degrees of freedom, $P < 0.01$). Estonia had unusually high education scores due to higher-certificates from technical colleges in Estonia (Fig. 5), but the correlation remained strong if these were set to the level of an ordinary degree. Except for one study area in Turkey, average scores given for the benefits from food, recreation, tourism, aesthetics, business opportunities and regulatory ecosystem services (e.g. flood-water absorption) outweighed those for costs from wildlife damage to property, as pests, disease vectors and wildlife fuel sources. Perception of costs from nature did not correlate with education level ($r = +0.03$) or IT use. However, perception of benefits correlated weakly with use of computers in homes ($r = +0.64$, $P < 0.10$) and of the internet ($r = +0.59$, $P < 0.10$), with use of home computers and the internet extremely strongly correlated ($r = 0.98$, $P < 0.001$).

Table 2
Participations and cost-benefit attitudes surveyed in TESS local case studies.

Biodiversity-dependent countryside activities	Perceived benefits from wildlife
• Feeding birds or other wildlife	• Food
• Collecting wild snails, fungi, fruits, flowers or other plant materials	• Wildlife-related recreation (for instance bird watching)
• Doing outdoor pursuits (eg. walking/skiing/climbing/boating/camping/off-road cycling)	• Tourism
• Going horse-riding	• Other biodiversity-based source of income
• Making excursions in order to watch wildlife	• Aesthetics and other intrinsic value
• Cultivating a garden or lawn	• Environmental security such as flood protection
• Going fishing	• Other benefits
• Going hunting using a gun and/or with a dog or other animal (like a falcon, etc)	**Perceived costs from wildlife**
• Engaging in farming	• Damage from pest species to household food or property
• Engaging in forestry	• Damage from pests, predators or weeds to livestock, crops or woodland
	• Increasing the risk of fire
	• Increasing the risk of flooding
	• Transmission of disease to humans or livestock
	• Other issues

Household use of computers would be important for citizen engagement with a TESS. Familiarity of households with computers was most obvious in Estonia, Hungary, Poland and UK (Fig. 6), but quite low in Romania and the Egirdir area (Turkey 1). Asking questions for households may have hidden some details: in Greece, for instance, respondents noted that computers at home were mostly used by their children. Computers were mostly used at work by respondents in Greece, Estonia, Hungary and Poland, and less in Romania, Turkey and Portugal. However, computers were seldom used for internet purchases, which might provide commission revenue for a TESS, except for Estonia and Hungary followed by UK and Poland. In conclusion, people across case studies areas were familiar with computers, although this capability sometimes resided in household members other than the questionnaire respondents; the internet was used by most that had computers, but to a lesser extent for purchases, which may show distrust of such services or poor development of internet retailing. Use of computers at home, work or for the internet did not correlate significantly with education levels ($r < +0.37$), but there was a weak correlation across the case studies of internet retailing with education levels ($r = +0.60$, $P < 0.10$). Nevertheless, internet retailing had a strong relationship with benefits perceived from nature ($r = +0.83$, $P < 0.01$).

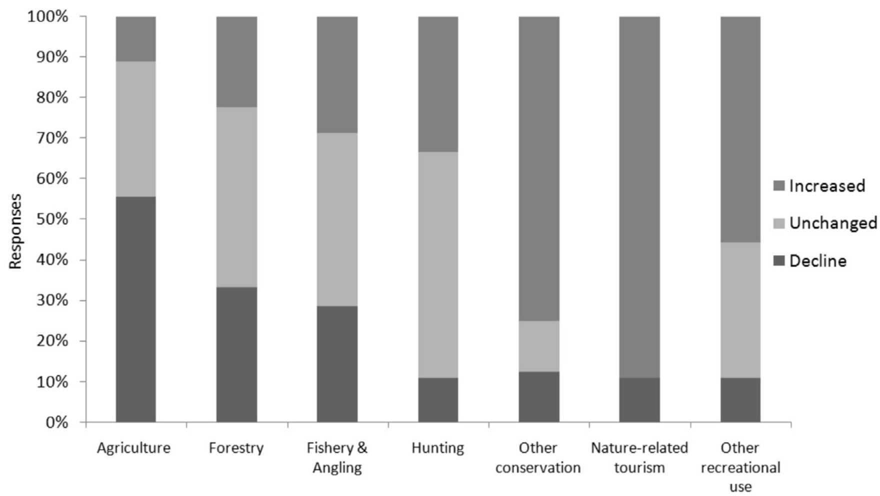

Fig. 3. Assessment by case study teams of changes in ecosystem services during the last 20 years.

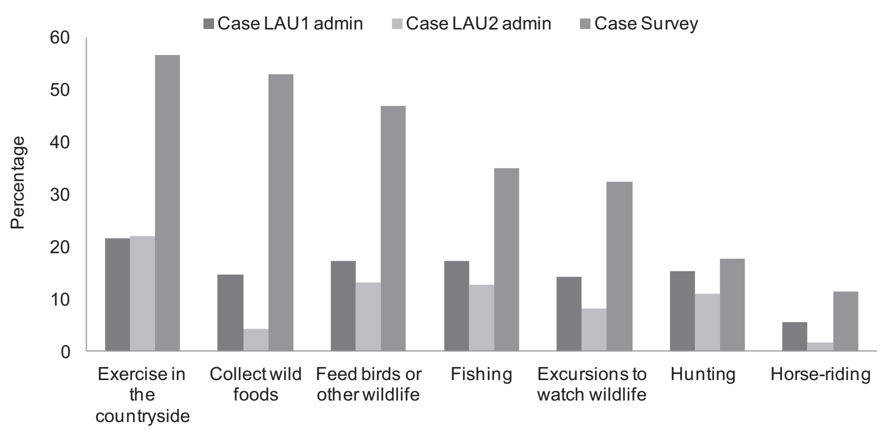

Fig. 4. Participation in countryside recreational activities, comparing averages across case studies for local authority estimates with proportions recorded in surveys of individual citizens.

5.2. Mapping project

For mapping, project partners provided tablet PCs to the helpers. The project aimed for easily acquired tablets, with a screen readable in sunlight, robust, low weight, GPS enabled, camera, mobile internet, long time battery and of affordable cost by local individuals. However, case studies were conducted just before the tablet PC market boom initiated by the Apple iPad, which should facilitate mapping activities in the long run. Mapping software was developed for the project and translated into all the languages of the case studies areas to test whether the local residents would be able to perform mapping activities with very little training but a very user-friendly tool. Translation was defined by the helpers at an early stage as an absolute prerequisite; after a period of beta testing, the Mapper (available for download in most European languages from www.naturalliance.eu) was distributed to the teams. The Mapper used images obtained online from Google Earth (Fig. 7).

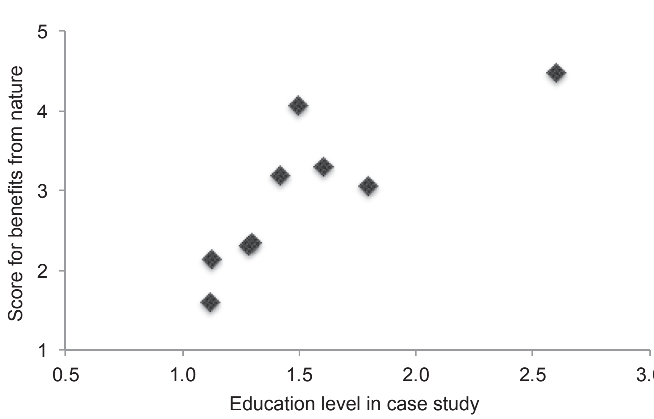

Fig. 5. Average scores (of 1–5) for benefits from nature from case study citizens correlated with average education levels (1 = school, 2 = university or technical college, 3 = higher degree).

The mapping project in the Greek case study area included three subprojects:

1. Paths used by wild boar (presented in Fig. 7)
2. Paths used for riding horse
3. Paths used by walkers and climbers

The Greek volunteers had the tablet PC in their possession for 10 days each. The study area for all three subprojects was just north of the 'Ano Poroia' village, in the municipality of Kerkini, Prefecture of Serres, Greece. This is heavily forested with oaks, beech and pines. The density of the forest is such that it is difficult (if not impossible

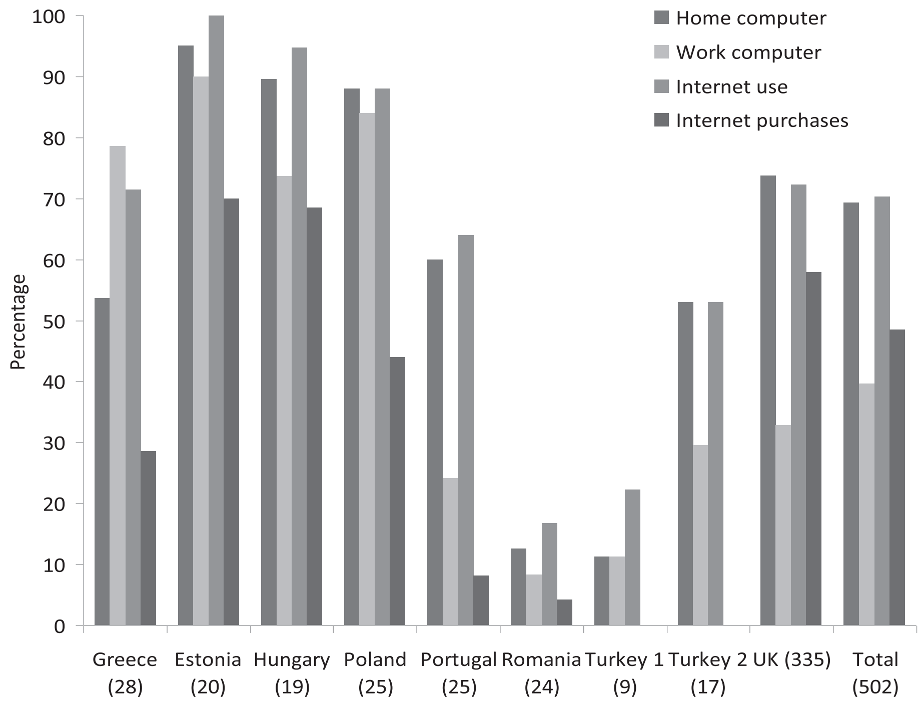

Fig. 6. Computer and internet use in case study areas.

in some cases) to map paths using Google Earth images, as the vegetation screens them from the satellites. Wild boars are one of the main game species of the area; in the recent years there has been much tourism development and a lot of hunters are drawn to the area. Therefore, successful game management, following widely accepted sustainability directives, is important for the local community. Apart from TESS volunteers who performed the mapping exercise, a local hunters' association showed interest in

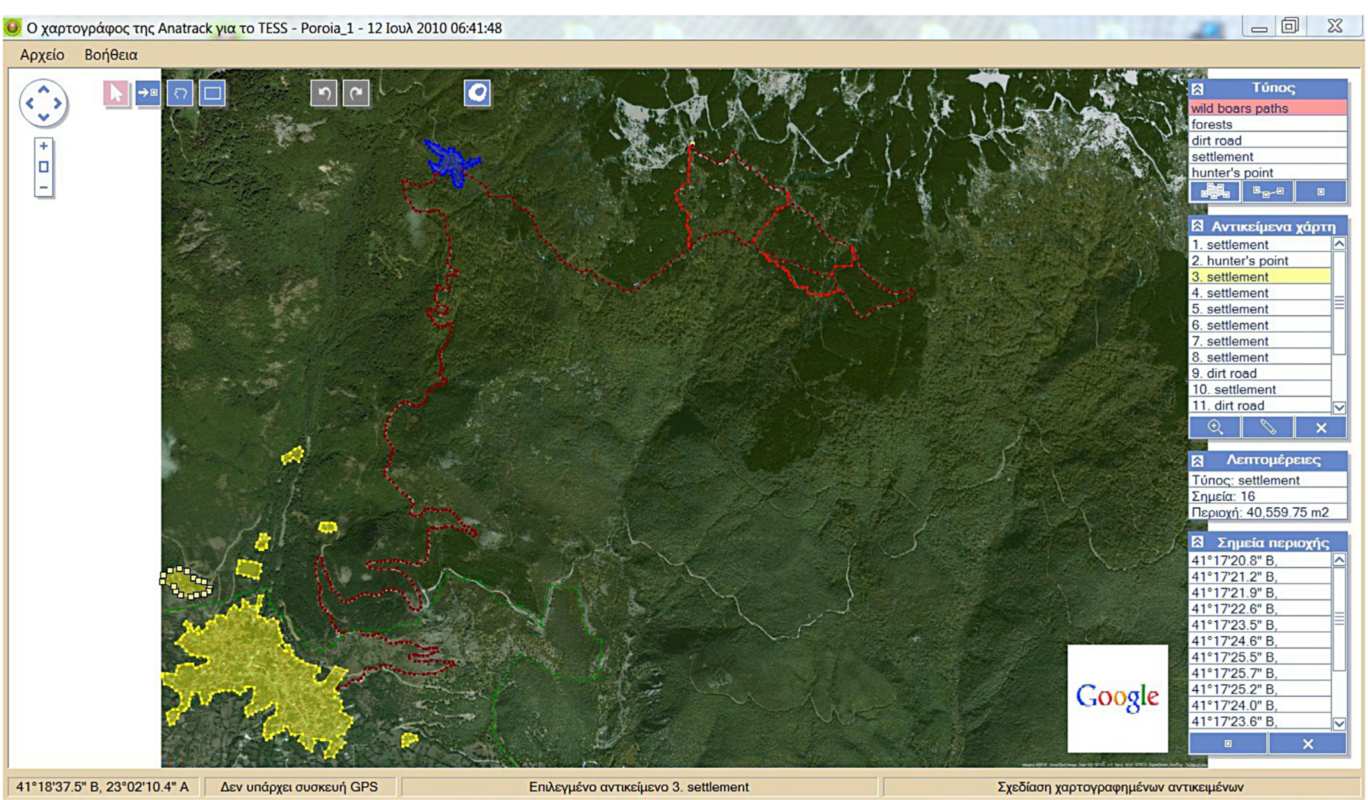

Fig. 7. The TESS mapping routine operating in Greek for the Kirkini case study area; the large lower polygon is the 'Ano Poroia' settlement, and mapped lines are travel routes of wild boar and hunters; the small upper polygon is an open area used by local hunters as a gathering point.

the software and TESS in general, although there was a low level of computer experience among its members.

5.3. Helpers

The number of helpers involved in all case studies was 46. Conclusions drawn from the helpers' responses provided useful results on (i) local residents' motivations to participate in the project and (ii) their future information needs. Motivations listed without prompting for participation in the project fell into four categories:

a) professional interest, such as relation of the project to their academic and professional background, desire to acquire new knowledge and skills (i.e. GPS, mapping) for their careers, obligation to involve in similar projects because of involvement in local management or government;
b) social reasons, such as love for their community, desire to offer service to their community;
c) ecological reasons, such as interest in nature-related issues, willingness to protect the environment;
d) curiosity.

The survey also provided unprompted data on local residents' future information needs. Information needs varied across case studies but there were three major categories:

a) data on protected species and other information required for conserving biodiversity;
b) information on economic aspects of ecosystem services;
c) geographic data (e.g. geolocation, images) for other purposes (security, access etc.)

Beyond the unprompted data that provide a qualitative analysis of helper interests, lists of background and project assessments factors were given for them to score. Helpers put a high priority on better GPS capabilities, a better map than the simple Google Earth images, screens more sensitive to touch and more visible in sunlight, less weight and longer battery lives. Background data indicated (Fig. 8a,b) that in most case studies areas there had been no other similar projects; the exceptions were for Greece (mapping of walking paths), UK (mapping of species, recreational value, cultural value, aesthetic value), Hungary (species) and Poland (land-use). The majority of helpers had no previous experience with mapping equipment (Fig. 8b), which gave a useful perspective in their

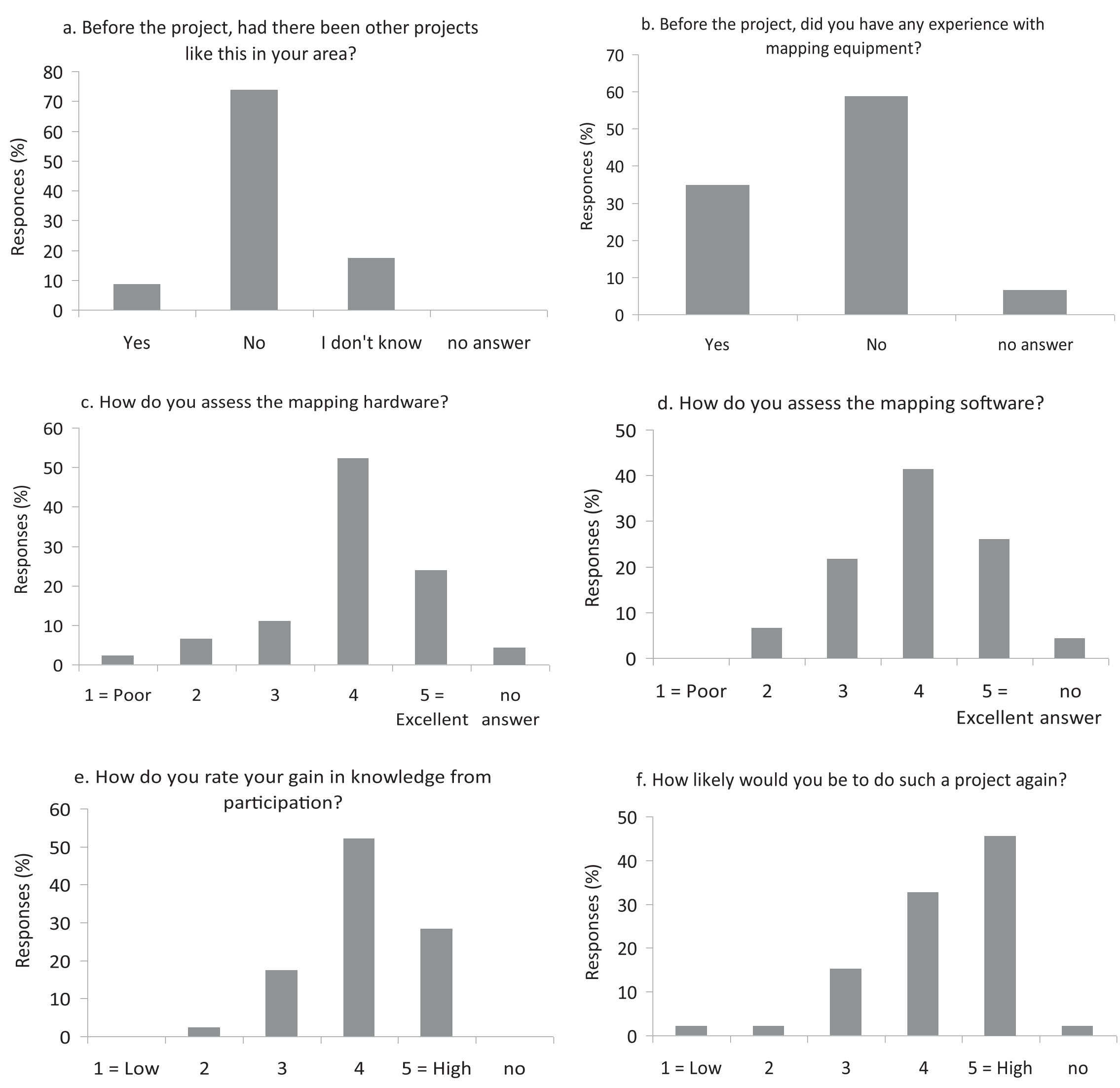

Fig. 8. Assessments of the mapping project by Helpers.

assessment of mapping equipment: they rated the mapping hardware and software reasonably highly (Fig. 8c,d). The vast majority of helpers considered that they gained knowledge from their participation in the project and would be willing to participate in such projects in the future (Fig. 8e,f).

An extremely high percentage (96%) thought that such projects should be supported nationally too. This response was presumably largely due to the great interest most helpers had in their community, the protection of their natural environment and especially the benefits they were expecting from implementing this kind of project (acquiring new skills, identifying new methods for sustainable use etc).

It is also worth noting that mapping was in several cases even more ambitious than in Kerkini (Fig. 7). The mapping of hares by hunters in Germany (Table 1) was part of population assessments that are increasingly widespread as a standard routine in European countries for ensuring sustainability of hunted resources. In the UK too the mapping of deer and their habitats was not only very detailed, but also formed part of a much more extensive Agenda 21 assessment of local requirements that is conducted by the local authority at 5–10-year intervals for planning purposes.

6. Conclusions

This paper shows the high importance and complexity of a multidisciplinary approach needed to a topic which appears primarily technical. The first part shows an abundance of theoretical, technical and biological information already available for designing an environmental decision support (Sections 1–4, Figs. 1–2). It is therefore perhaps surprising that more has not been implemented. The likely reason for inability to convert the knowledge is lack of study of the socio-economic design requirements, which are shown by Section 5 also to be complex. They are not only changing at local level (Fig. 3), perhaps partly as a result of improvements in education (Fig. 5), but the extent of associated socio-economic resource is not appreciated by government (Fig. 4). Nevertheless, development of home computing facilities (Fig. 6) predisposes Europe's citizenry to environmental support software. Very possibly, in view of their mapping skills (Fig. 7) and interest in mapping at local level (Fig. 8), such decisions support will eventually be delivered via GIS to tablets in the field.

Motivations of local residents' to participate in both the socio-economic and mapping project varied from desire to acquire new skills and knowledge to love for their community and interest in nature-related issues. They desired, as did local authorities in surveys across the whole of Europe (Kenward et al., 2013a) more data regarding biodiversity (species etc.) as well as information on possible economic benefits from conserving their natural resources. Robust, continually updated and easily and freely accessed databases, both from outside the TESS system but linked to it and developed through the TESS system would be welcomed, especially if they are capable of providing data for the very local level. The helpers' mapping capabilities and willingness to participate voluntarily in such projects indicated that they could contributed effectively to collecting such data, which can then be used in DSS for local management of land and species and, if participation is wide enough to give good map coverage, to support policy and planning at higher levels.

Across all case studies, local people appeared to be in position to provide:

a) data regarding mostly previous mapping and other relevant projects, if any;
b) data on species/habitats if it is made simple enough to collect; and
c) data on main occupations and economic activities (i.e. ecotourism activities, farming etc.).

On the other hand, local participants encountered problems in planning the socioeconomic projects. Main reasons for this were lack of IT education and training, mistrust between the locals as well as towards authorities, lack of necessary data, complicated decision making processes and the fact that local people are not fully aware of the opportunities for activities related to biodiversity. Therefore, if DSS are to help local management, systems are going to need to become comprehensive as well as user-friendly. Moreover, provision of proper IT training, changing the form of interaction between participants, provision of additional data, tailoring processes to facilitate the local decision making processes and activities aimed at awareness are also required.

Extending such work through web-services without direct engagement of researchers like the TESS teams will also be challenging. However, it has become far more practical with experience gained in TESS and because broadband and Wi-Fi connections are expanding and the local population (especially younger generations) are becoming more and more familiar with the web and digital maps for navigation on smart-phones. Local primary and secondary schools are equipped with computer labs (to some extent). The employees of the local municipality authorities are for the greater part familiar with the internet technologies and use it in every day work. Facilities can be expected to change rapidly, i.e. in the next 3–4 years. Nevertheless, much work is needed aiming at motivating the local community in order to endorse new and emerging technologies, especially web based ones, towards using internet based tools for the protection of their local habitats.

Local residents across case studies had a rather positive attitude towards biodiversity, as indicated by a positive balance of perceived benefits to costs from biodiversity, and appreciation of benefits increased with levels of education (and most sophisticated use of IT). Their engagement in particular activities (feeding birds and/or other wildlife, collecting wild snails, fungi, fruits, flowers or other plant materials, doing outdoor pursuits, going horse-riding, making excursions to watch wildlife, fishing and hunting) was very considerable. It was also not appreciated by local authorities, perhaps because perceptions are still adjusting from a tendency for reducing employment on the land for farming and increasing engagement in recreational activities, which need new management skills and can in turn provide new employment.

However, a question of whether they could use the models included in the TESS database with the spatial data they gathered would in almost all cases have had a negative answer. The vast majority of these models are not user-friendly enough to be used by non-scientists. There is therefore a considerable opportunity to provide this scientific knowledge as decisions support tools for local people, but also a considerable challenge. Local citizens were asked to gather credible data, and this they did. To complement this successful citizen science, further project work must now show whether DSS can be made simple enough for easy use in conjunction with their efforts.

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