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Establishment of a cross-European field site network in the ALARM project for assessing large-scale changes in biodiversity

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Abstract The field site network (FSN) plays a central role in conducting joint research within all Assessing Large-scale Risks for biodiversity with tested Methods (ALARM) modules and provides a mechanism for integrating research on different topics in ALARM on the same site for measuring multiple impacts on biodiversity. The network covers most European climates and biogeographic

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regions, from Mediterranean through central European and boreal to subarctic. The project links databases with the European-wide field site network FSN, including geographic information system (GIS)-based information to characterise the test location for ALARM researchers for joint on-site research. Maps are provided in a standardised way and merged with other site-specific information. The application of GIS for these field sites and the information management promotes the use of the FSN for research and to disseminate the results. We conclude that ALARM FSN sites together with other research sites in Europe jointly could be used as a future backbone for research proposals.

Keywords ALARM · Multiple pressures · Risk assessment · Biodiversity · Field site network · Global change

Introduction

European research lacks a cohesive site network to test, monitor and map different large-scale environmental pressures on biodiversity in order to answer questions of high ecological and political importance such as how, where and to which degree is climate change and global change impacting European biodiversity. The questions are numerous, but the answers were, in the past, often only provided for bilateral relationships, on a local scale, or for a few European countries. Investigating impacts on biodiversity caused by climate change needs a large-scale network of sites, where these impacts can be assessed, spanning all important biogeographical regions of the continent. Most research sites used by scientists are only investigated for a short term or a specific research topic, and complete coverage of European biogeographic zones is not given.

ALARM goals

When the EU integrated project Assessing Large-scale Risks for biodiversity with tested Methods (ALARM, www.alarmproject.net) (Settele et al. 2005) started under Framework 6 in the year 2004, a continent-wide European network of testing sites or field sites for monitoring impacts on

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biodiversity did not exist. Therefore, it was an integral part of the project to set up a cross-European network of sites to test or measure impacts on biodiversity. ALARM research focuses on assessment and forecast of changes in biodiversity and in ecosystem structure, function and dynamics. Specifically, a number of risks arising from climate change, environmental chemicals, biological invasions and pollinator loss in the context of current and future European land-use patterns are assessed.

While detection of species ranges in Europe is possible by mapping the existing population ranges (Walther et al. 2005; Araújo and Rahbek 2006), shifts in species ranges and local population extinctions in some organisms such as wild bees need long-term monitoring on field sites. Only then impacts and risks on these populations can be assessed as demonstrated by a study that revealed parallel declines of bees and insect-pollinated plants (Biesmeijer et al. 2006). Knowledge on the concerted action of all these factors is poor and ALARM is the first research initiative with the critical mass needed to deal with such aspects of combined impacts and their consequences. The ALARM project consists of four general objectives: (1) to develop an integrated large-scale risk assessment to biodiversity as well as terrestrial and freshwater ecosystems as a part of environmental risk assessment; (2) to focus on risks as a consequence of climate change, environmental chemicals, rates and extent of loss of pollinators, and biological invasions; (3) to establish socio-economic risk indicators related to the drivers of biodiversity pressures as a tool to support long-term oriented mitigating policies and to monitor their implementation and (4) to develop a research network that is consistently thinking, interacting and investigating on a continental scale across different environmental problems (impacts) and across different spatial and temporal scales of ecosystem diversity changes.

To achieve the objectives mentioned above, ALARM consists of seven modules: four natural science modules, the socio-economics module, a sixth module of cross-cutting analyses of multiple pressures across landscapes and a seventh module which includes training activities, dissemination of scientific results, promulgation of toolkits as well as information and expert systems developed and tested within the ALARM project.

Aims of the ALARM field site network

There are two central issues for setting up the field site network: first, the establishment of a site network as an arena within which to examine the separate and interacting effects of the multiple pressures concerned in ALARM, and second, as a testing ground for the risk assessment tools developed during the project.

The field site network (FSN) provides the necessary testing ground for aspects of all four natural science modules of the ALARM research program. It is established with a comprehensive geographical and environmental coverage of Europe. It allows detailed monitoring of environmental variables, species distributions and ecological interactions in a locally intensive but geographically extensive manner, providing a unique continent-wide perspective on the issues addressed by particular research programs within ALARM. The FSN allows the use of long-term field sites to estimate risks to biological diversity, and plays a central role in conducting joint research within all ALARM modules. Furthermore, it allows integration of research on different topics in ALARM on the same site for measuring multiple impacts on biodiversity. All sites include freshwater as well as terrestrial habitats, including both lotic and lentic environments. The FSN covers most of European climates and biogeographic regions, from Mediterranean environments through central European and boreal zones to the subarctic.

Objectives of the ALARM field site network are: (1) to establish field experimental plots within paired field sites; (2) to continue collecting current and historical remote-sensing data and associated information; (3) to develop detailed field protocols for use across the site network; (4) to organise field teams to perform replicated research protocols at all sites and last (5) to collect and analyse field data and feeding it back to the main research modules.

Establishing field experimental plots within field site

To provide the necessary testing ground for aspects of all four modules of the ALARM research programme, a site network had to be established with a comprehensive geographical and environmental coverage of Europe. This network of sites would ideally span the continent as shown in Fig. 1. The idea was to have a large-scale network with even-spaced sites across Europe, in which the testing sites are placed according to the FSN selection criteria.

These areas are arranged in a nearly regular grid across Europe, at approximately 800 km apart, although slight variations have been required to fit the irregular outline of the continent (Fig. 1). The final site list deviated from that shown in Fig. 1 due to availability of appropriate field sites, access issues or other logistical considerations.

Study design and FSN selection criteria of the field sites

Each of the focal areas consists of two study sites, each 4 × 4 km and within 50 km of each other. Paired study sites are chosen to be as similar as possible in abiotic conditions, such as elevation, geology, type of landforms and soils, hydrology and other environmental parameters so that human disturbance and land-use intensity is the main distinction characteristics between the two sites: (1) extensive areas dominated by semi-natural vegetation, with some agriculture embedded. The "natural" site of the paired sites is located here; (2) areas dominated by extensive agriculture, with remnants of semi-natural vegetation. The "disturbed" site is located here.

The ALARM-wide field site network for testing multiple pressures at the same location all over Europe is a central part of the consortium management and has been playing an intense role

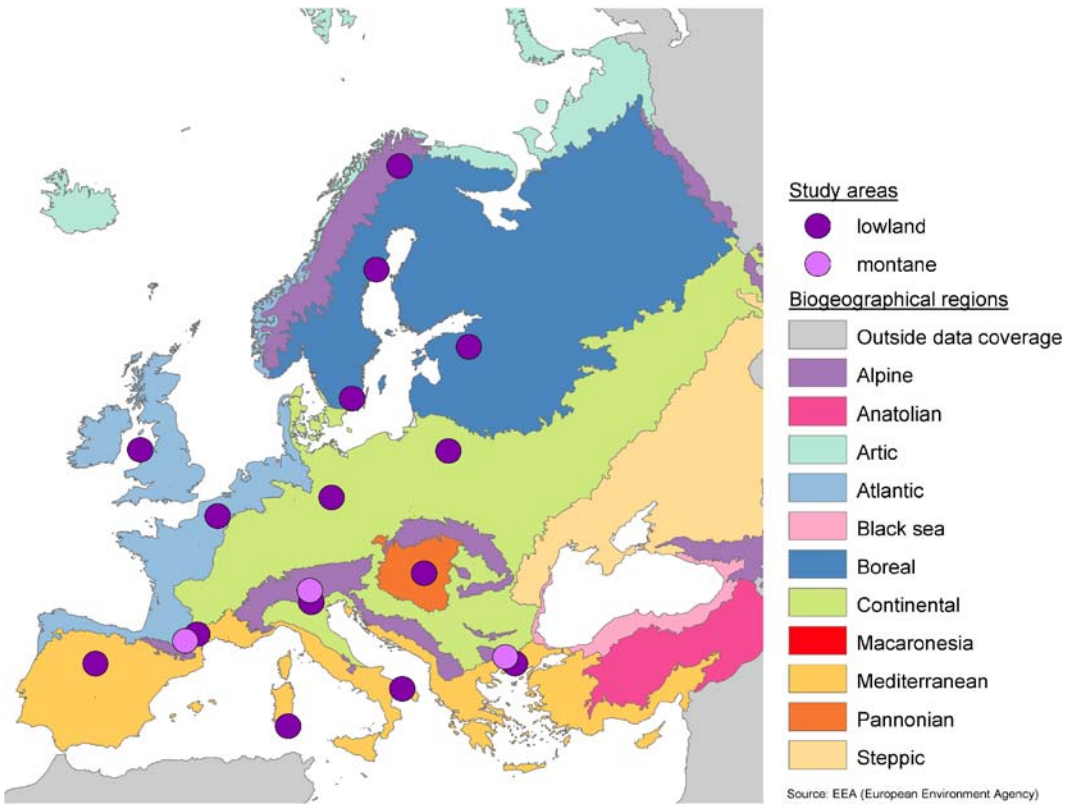

Fig. 1 Proposed outline of the ALARM site network

for integrating research in ALARM for the years 2006 and 2007. By the year 2007, 16 field sites have been selected and assigned into the core field site network of ALARM. Another three associate partners, partners who have not been in the original project consortium but later got funds to run their field sites for ALARM, provided their sites as ALARM FSN field sites. All these FSN sites are in principle open to any researcher outside ALARM to make use of them provided they are working on similar topics. The core sites of the FSN are those used by partners in the pollinator and environmental chemical modules because they were the most suitable for all research topics, with additional sites based on other EU-projects.

At the start of the site selection process, we gathered information by questionnaires sent to all ALARM partners on (1) the field sites where partners work, (2) the field site characteristics necessary and sufficient to carry out research planned by the partners in ALARM, (3) the projects (both those involving a single module and those being of a more integrative nature) that the partners planned or were thinking of pursuing in later stages of ALARM. Selection process did not only involve ALARM partners but also partners and their input from Greenveins (Schweiger et al. 2005; Herzog et al. 2006), BioAssess (Waser et al. 2004), BioPress (Brown et al. 2002), Alter-Net (Parr et al. 2003), LTER-Germany, LTER-Austria and LTER-Europe (http://www.lter-europe.ceh.ac.uk/index.htm, http://www.ilternet.edu/). This has led to the incorporation of a Greenveins' site and a Long-Term Ecological Research (LTER) Network site in the ALARM field site network FSN in 2007 (e.g. Gumpenstein in Austria) plus three more sites from new partners in ALARM complementing the FSN network of altogether 16 sites.

There were several advantages with the FSN selection process: (1) the number of field sites; (2) the size of them and (3) the standardisation of the selection process. The FSN has many sites compared to previous EU projects which had a considerably smaller number of field sites with an incomplete coverage of environmental heterogeneity within the continent. The size of each field site is large enough to include landscape-scale heterogeneities and all or many of the important habitat/land-use types occurring in a region, enabling research to cover landscape-scale questions as well. Having a pair of sites provides a better characterisation of each regions (spans the within-region variability) and provides a landscape-scale "treatment" which is consistent throughout the site network across Europe. The standardisation of site selection is a major advantage. Participants did not simply choose a site (within each region) that they liked, or had previous studies going on, but were instructed on how to choose, thus leading to a higher degree of comparability.

Selected ALARM field sites

Research has been carried out on the 16 field sites (we are open to suggestions for additional sites), which from north to south are the following (location given in Fig. 2): Abisko (Northern Sweden), Uppsala (Central Sweden), Tartu (Estonia), Maisiagala (Eastern Lithuania), Galway (Western Ireland), Berkshire (Southern England), Göttingen (Central Germany), Ile de France (Northern France), Krakow (Southern Poland), Gumpenstein (Central Austria), Kiskun (Hungary), Meolo (Northern Italy), Fruska Gora (Northern Serbia), Garraf (Northeastern Spain), Toledo (Central Spain) and Lesvos (NE Aegean island, Greece) (Table 1).

The field site in Abisko (Northern Sweden) does not have a disturbed site due to a lack of anthropogenic influence in the area. All other sites show the paired design.

Most sites are managed by ALARM partners (Lund University; Swedish University of Agricultural Sciences; University of Tartu; Jagiellonian University Krakow; University of Reading, School of Agriculture; University of Bayreuth UBT; Centre for the Balkan Biodiversity Conservation FSUNS and the Institute for Biological Research of the University of Belgrade; National Institute of Agronomic Research (INRA); University of Castilla-La Mancha; Center for Ecological Research and Forestry Applications (CREAF); University of Milano Bicocca; University of the Aegean) and cooperation with other projects or networks led to the incorporation of a few sites hosted by new associated partners (Austrian Federal Environment Agency (UBA); University of

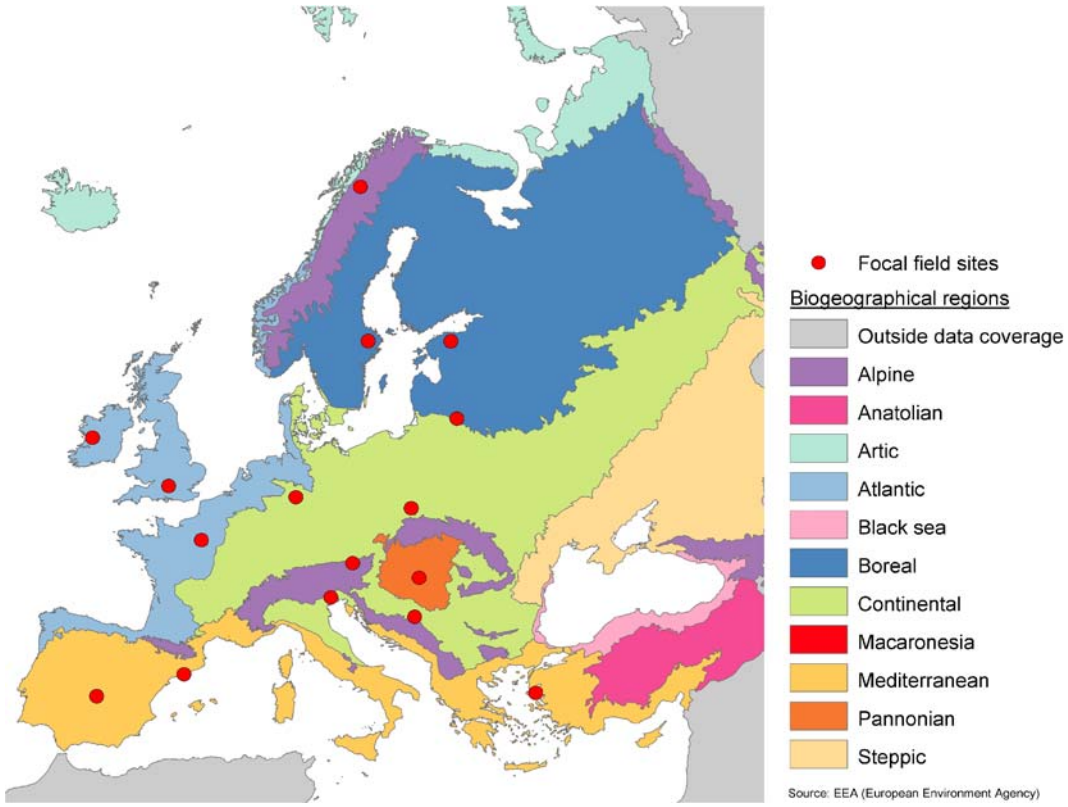

Fig. 2 Realised ALARM field sites network across biogeographical regions of Europe

Table 1 Field site, their location country and the biogeographical region (north to south)

Field site name	Country	Biogeographical region
Abisko	Sweden	Alpine
Uppsala	Sweden	Boreal
Tartu	Estonia	Boreal
Maisiagala	Lithuania	Boreal/Continental
Galway	Ireland	Atlantic
Berkshire	Great Britain	Atlantic
Göttingen	Germany	Continental
Ile de France	France	Atlantic
Krakow	Poland	Continental
Gumpenstein	Austria	Alpine
Kiskun	Hungary	Pannonian
Meolo	Italy	Continental
Fruska Gora	Serbia	Continental
Garraf	Spain	Mediterranean
Toledo	Spain	Mediterranean
Lesvos	Greece	Mediterranean

Dublin, Trinity College; Centre National de la Recherche Scientifique Gif-sur-Yvette (CNRS); Institute of Ecology and Botany of the Hungarian Academy of Sciences; and the Institute of Ecology of Vilnius University).

Field site data and associated information

Information on the FSN sites has been prepared by the site managers, then collected and distributed within the project. Information on climate, soil, geomorphology, topography, land use as well as pictures were essential for researchers in ALARM to develop research protocols and tests, since most of the tests were developed by remote researchers who had not been personally at the sites. Maps were processed for the sites, first on the field sites as topographic maps or LandSat satellite pictures (Fig. 3) as well as digital elevation maps, to give remote researchers the

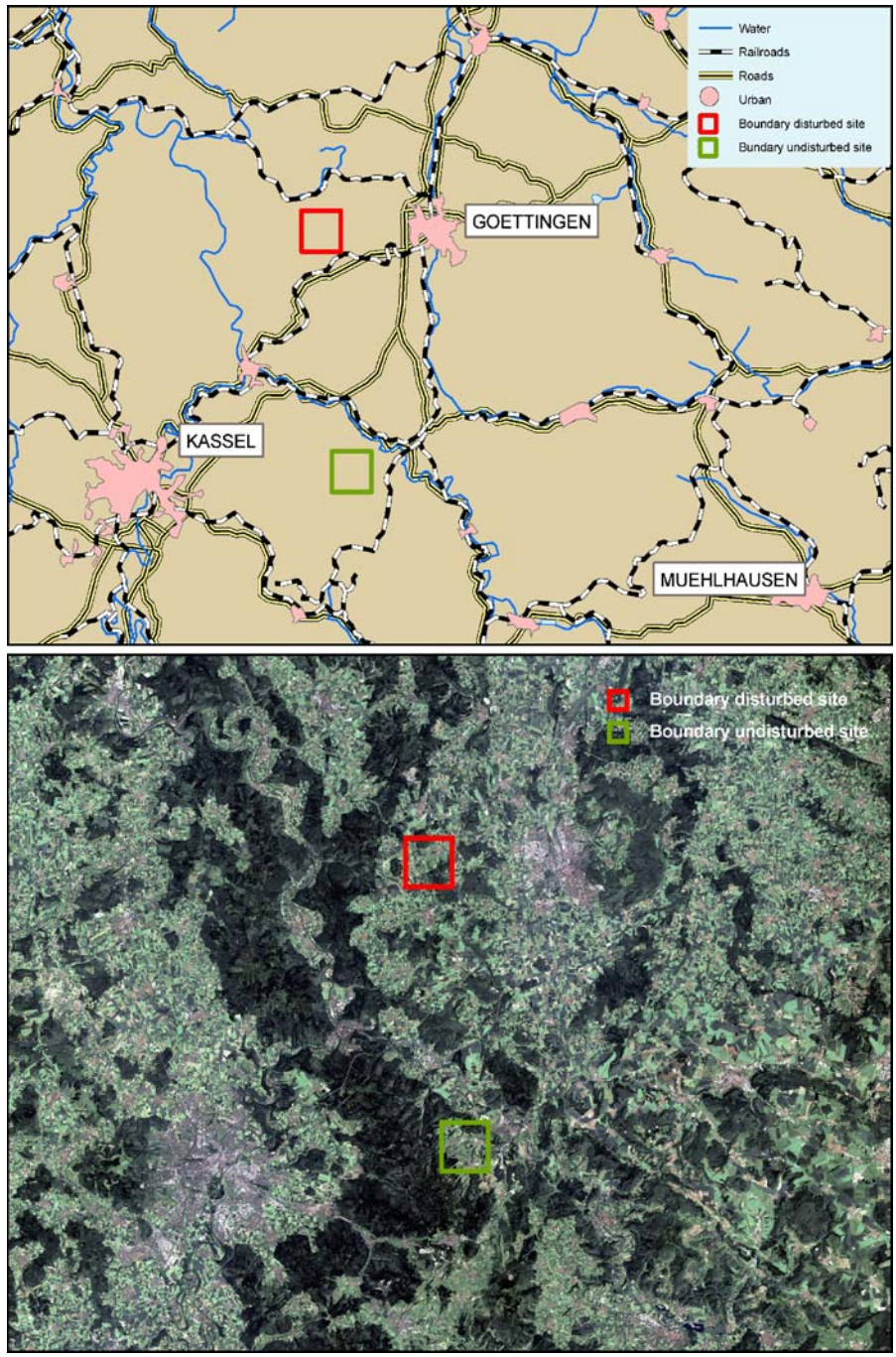

Fig. 3 Topographic maps and satellite pictures about the focal areas (here site Göttingen, Germany)

possibility to get an impression about the focal area without scientists having to visit the sites.

The disturbed and undisturbed sites were identified by red and green frames leading in the next step to either the disturbed or undisturbed site for more detailed information and maps. Photographic images and contact details for each field site were completed for information gathering and processing.

European-wide GIS information for each site

The more detailed layers of standardised maps were provided based on CORINE land cover 2000

vector data (from EEA) of both 4 × 4 km test sites of each paired site (Fig. 4). While field sites need data on a local scale, the data for all field sites should be comparable in a European context, therefore standardisation and scaling of data was an important issue at this point of research.

The scale of this data is approximately 1:100,000. Other European datasets available such as the European soil data base (grid based 1 × 1 km data, original scale 1:1,000,000) and a worldwide digital elevation model (GTOPO30, 1 km elevation grid, source US Geological Survey) could not be used for field site representation because of their inappropriate scale. Concerning ALARM research, different types of data, such as point data, line data, polygon data and raster data, will be obtained in the future. A mapserver is available where the data can be integrated and stored. Other data are not available at present. At some of the field sites partners use their own geographic information system (GIS) and collect information and data about the field sites, sometimes only analogue maps or raster data. These maps should be available for all field sites, sufficiently simple while providing enough information, and being able to integrate as many research topics (biological, chemical, climate) in ALARM as possible and in a standardised manner.

Currently, the data are accessible via internet at two web mapping services. One service covers the entire project and focuses on European data, the other is especially developed for the FSN. In this way, information is provided to partners and to the public. One mapserver is only available for registered users. The field site mapserver is open for all at the webpage "www.alarmproject.net" using the menu entry "Field Site Network". The data shown in this service will be extended when results of the field research are available.

GIS integrates the project in several aspects: since data sources, maps and software vary within ALARM, communication and standardisation across scientific fields is necessary. Also the heterogeneity of the research topics within the project, ranging from environmental chemicals and climate change to invasive species and the loss of pollinators, is integrated via the same location using GIS. Additionally, the proposed output of ALARM research consists partly of large-scale maps or tools derived from all over Europe. As scale is a central issue for scientists when assessing large-scale risks from local research, the European data (scale at least 1:100,000) have to be derived on the basis of locally obtained data (scale 1:10,000). Besides, data on the local scale are quite different in quality and quantity across locations. By using common protocols for the field site research, the results are standardised data on a local scale which then can be used to derive European-scale maps.

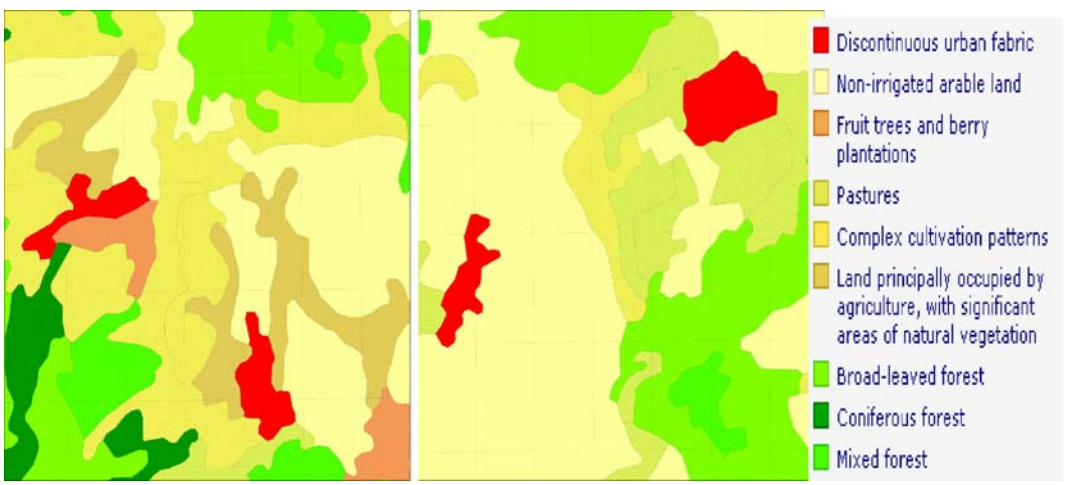

Fig. 4 Example of an ALARM map showing CORINE land use for two field sites of a focal area (Göttingen, Germany). *Left* is the undisturbed site and *right* the disturbed site of Göttingen

Field protocols for use across the site network and field work teams

After establishing the research sites, standardised and detailed field protocols were designed for the use across the site network to assure quick and simple data collection and transfer for ALARM research. At each site, a site manager was selected and a field assistant chosen and trained to perform the research protocols that were replicated at all sites. Field data were then collected, analysed and fed back to the main research modules. This work programme allowed detailed monitoring of environmental variables, species distributions and ecological interactions in a locally intensive but geographically extensive manner, providing a unique continent-wide perspective on the issues addressed by particular research programmes. Senior researchers, representing the research modules of ALARM, assisted the field site programme. These researchers were responsible for working with their module teams to recommend a set of research priorities for use of the site network to advance their module's work. These activities involved partly direct observations or the collection of samples to be analysed elsewhere. The coordinators of the site network met together once each year to combine their separate research plans into a complete FSN work protocol to be performed during the following field season by field site teams.

A number of research teams within the ALARM consortium proposed specific research protocols for that year, with precise descriptions of the methods to be employed, any training that was necessary, constraints on the timing of the work and the approximate time demands on the field staff. The field research coordinators of each research team prioritised together the research and reconciled conflicting demands on time and resources to bring these into a single, practicable research agenda for each field team. Funds were allocated for hiring field staff and carrying out the protocols.

Each researcher associated with the field site network had administrative responsibility for a subset of the sites. In addition to being involved in selecting field sites and experimental plots for each site under their supervision, the researchers were responsible for working with local programme staff to recruit and supervise field assistants. A team of one to two field assistants were recruited to perform research at each field site each year. Where possible, these field assistants were recruited locally. They worked under the supervision of the site manager and local ALARM partners. Samples and data collected by the field research teams were distributed back to the relevant leading research team.

Local biodiversity at the field sites

Local biodiversity at the field site network covers a wide range of European flora and fauna generally representing common biomes.

The Estonian field sites Tartu are characterised by Norway spruce dominated natural mixed coniferous forests, arable fields and cultivated grasslands. In natural habitats for the region, like old-growth boreo-nemoral forest, the biodiversity is relatively high. The forest floor vegetation is diverse and contains typical old-growth forest species (Moora et al. 2007), which is decreasing in many regions of Europe due to habitat loss. Particularly high diversity of root inhabiting symbiotic arbuscular-mycorrhizal fungi has been detected here (Öpik et al. 2008).

The region around the field site Berkshire, UK, is characterised by mixed arable farming and semi-natural habitats comprising broad-leafed woodland and calcareous grassland fragments. The natural site is composed of calcareous grassland and broad-leafed woodlands with some mixed arable farming and pasture, including the Local Nature Reserve Hartslock. The disturbed site is dominated by mixed arable farming with a small amount of mixed woodland and park.

Site Göttingen in southern Lower Saxony, Germany, is characterised by calcareous grasslands, orchard meadows, fallows and fragments of grassy banks and the main land use types are arable fields, forests and settlements.

The site in Krakow, Poland, is characterised by wet grasslands with dominant community of *Molinietum caerulae* and settlement with extensive agriculture.

The field site Kiskun, Hungary, is located between the rivers Danube and Tisza in Pannonian

biogeographic zone. Remnants of the natural vegetation and associated biota are: sand grasslands, poplar-juniper woodlands, meadows, alkali steppes, alkali lakes and marshes. The site represents a typical Pannonian inland sand dune system, with a slightly undulating surface and associated heterogeneity in habitats. Habitats range from wet meadows at low elevations, through croplands, vineyards, old fields, pine plantations, juniper-poplar woodlands and open grasslands (grazed or ungrazed) at high elevations. Its high species diversity results from the high habitat heterogeneity and the transitional character of climate and vegetation (forest-steppe). Of particular importance is the natural vegetation of sand dune tops hosting species endemic to the Carpathian Basin.

The site in Garraf, Catalonia, Spain, is characterised by shrublands and pine forests and vineyards. Similarly is the site in Toledo, Spain, characterised by Mediterranean shrublands (*Cistus ladanifer*, *Erica* spp.) and woodlands (*Quercus ilex*, *Quercus pyrenaica*). Agriculture in the area is cereal and other land use includes grazing by goats. The site in Lesvos, Greece is also characterised by Mediterranean shrub (low and high *phrygana*), olive groves and urban settlements.

Pesticides used at the field sites

The various study areas are extremely different and the answer about used pesticides is therefore not general answer but varies from field site to field site.

"The pesticides used are a function of the different permanent (e.g. orchard, vineyard, olive) and non-permanent (e.g. cereals, beet, rape) crops, environmental conditions and agricultural practices in the various field sites. Several different active ingredients are applied belonging to the three main groups of plant protection products: herbicides, insecticides and fungicides." For example are the main pesticides used at the field site Meolo Triazines, Acetanilides, Organophosphorus, Pyrethroids, Azoles and Ditiocarbamates. At Reading field site pesticides used are Cypermethrin, Lambda-cyhalothrin, Esfenvalerate, Deltamethrin, Chlorpyrifos, and Dimethoate. And at the Estonian field site Trifuralin and Fastac are used, while Dimetoat and Alfametrin was used at Kiskun, Hungary.

Impact of local agriculture on biodiversity

At many field sites, loss of semi-natural and natural features (woodlands, grasslands and hedgerows) are often associated with the absence of many floral and faunal taxa normally found locally in uncultivated or low-intensity farmed areas. Agrochemicals may also have reduced the diversity of some flower and invertebrate communities.

The main biodiversity driver of Estonian FSN sites is land-use intensity. In particular, there has been habitat loss due to the changed land-use: modern silviculture with monoculture plantation system, abandonment of semi-natural grasslands and increasing area of arable fields.

Contrary is the situation at the Hungarian field site where conversion to cropland was historically the major threat to biodiversity in the region. Currently, the trend is the opposite, former agricultural lands are gradually abandoned. These old fields, if situated close to remnant natural habitats, have a high potential to regenerate and harbour a considerable amount of biodiversity. Light grazing is sustainable and is part of the traditional land-use in the region.

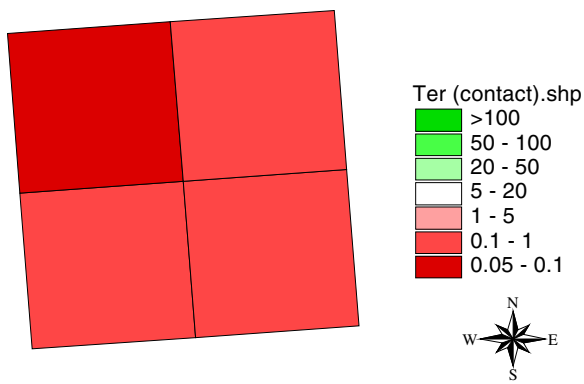

Fig. 5 Example of theoretical risk assessment for pollinators. The figure shows the distribution of TER by contact exposure in the 4 × 4 km Field Site of Meolo (Italy) a few days after insecticide application on vineyard (June 25 2007). A TER lower than 1 indicate a potential for acute toxicity

Ongoing research about a theoretical risk assessment, based on the distribution of pesticide concentration in the field sites and on the toxicity data for pollinators, indicates that, after insecticide application, high level of risk is likely to occur, reaching levels of potential acute toxicity (example Fig. 5). The figure shows the distribution of toxicity exposure ratio (TER) by contact exposure in the 4 × 4 km field site of Meolo (Italy) a few days after insecticide application on vineyard (June 25 2007). A TER lower than 1 indicate a potential for acute toxicity.

Specific ALARM information about the field sites

Climate change has eminent impacts on biodiversity and ecosystems and therefore climate change research plays a key role in ALARM. The central role is also mirrored in the field site network. We developed climate scenarios on a regular grid system for Europe (modified from Mitchell et al. 2004) and extracted the values for the grid cells of each focal area for the following parameters: mean temperature, mean precipitation and growing degree days for the time period 2001 to 2100, for 1 month only or the whole year. The climate scenarios are available as graphs and as data for the specific location. We used selected climate and Special Report On Emissions Scenarios (SRES) (Spangenberg 2007) socioeconomic scenarios for the field sites as well as an additional scenario for the break down of the thermohaline circulation of the North Atlantic Ocean. This provides research at the field sites with scenarios of potential future climates (Fig. 6). The climate scenarios (GRAS–HadCM3; GRAS-CUT–HadCM3; BAMBU–HadCM3; BAMBU–CSIRO2; BAMBU–PCM; SEDG–HadCM3) are based on selected global circulation models (HadCM3, CSIRO2 and PCM) for the SRES: Growth Applied Strategy (GRAS), Growth Applied Strategy Perturbed by a Climate Shock (GRAS–CUT), Business as Might be Usual (BAMBU), and Sustainable European Development Goal (SEDG) (Spangenberg 2007).

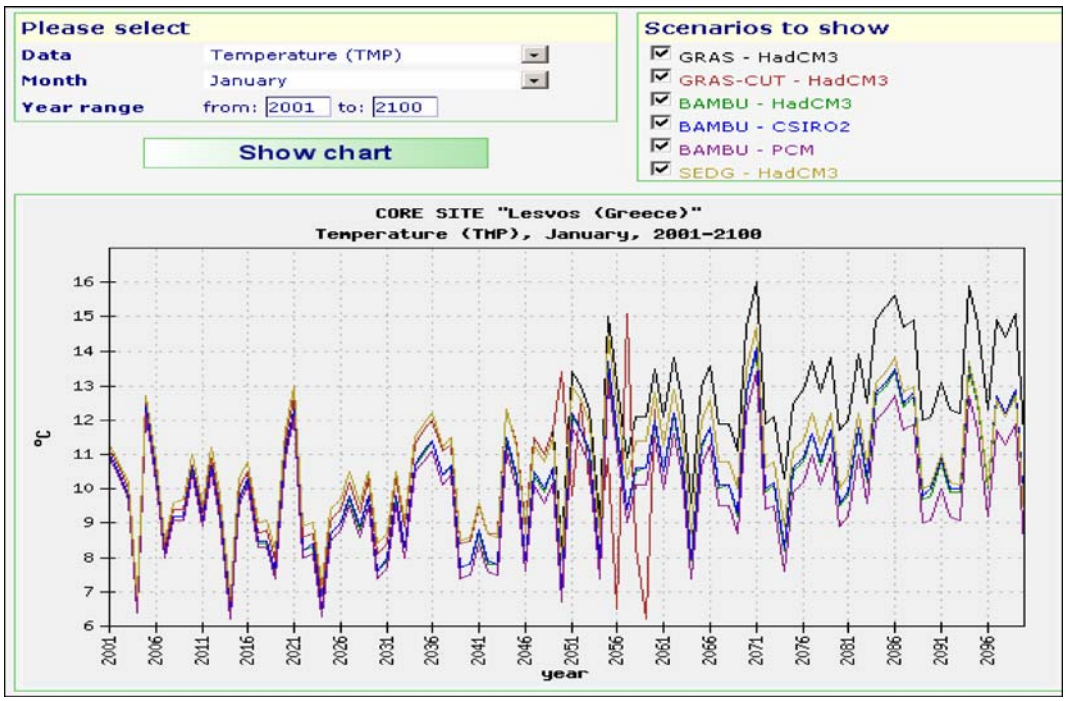

Fig. 6 Climate scenarios for the field site Lesvos, Greece

Outlook for the ALARM FSN

The FSN sites are established by ALARM partners, or through other projects including Greenveins (Schweiger et al. 2005; Herzog et al. 2006), BioAssess (Waser et al. 2004), BioPress (Brown et al. 2002) and Alter-Net (Parr et al. 2003). These sites are not permanent, although they are used previously by the respective partners. ALARM field sites are open to other scientists to use the facilities and cooperate on integrated research across different scientific fields providing research with an even broader basis. The ALARM field site network FSN provides a proper and extendable basis for research on pressures such as climate change, environmental chemicals, biological invasions and pollinator loss that will continue to impact our biodiversity in the future.

We hope that future initiatives can benefit from the labor and time invested in establishing the ALARM field site network and will use the network even after the ALARM project terminates in 2009. Therefore, a process was started within ALARM in order to find a future for the FSN beyond ALARM. Plans indicate an incorporation of at least some ALARM FSN sites into the Long Term Ecological Research Network (Parr et al. 2003) as a potential cross benefit for all. Furthermore, the LTER sites and the ALARM sites plus other research sites all together should be used as a backbone for future research projects, where research consortia are integrating all or specific sites into their proposal depending on research topics.

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