Systèmes d'Information à Référence Spatiale

ARCH Interreg Project

Assessing Regional Changes to Natural Habitats – photo-interpretation, mapping and study of the potential of new remote sensing technologies for monitoring natural habitats and biodiversity in the Nord–PasdeCalais and Kent regions

LOT N°2

STUDY INTO THE POTENTIAL OF NEW REMOTE SENSING TECHNOLGOIES FOR MONITORING NATURAL HABITATS AND BIODIVERSITY IN THE NORD – PAS DECALAIS CROSS-BORDER REGION

Report on Mission 2

"Inventory of Significant Experiences in Europe"

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• Summary

Beyond merely providing an inventory of significant experience and good practice carried out in the field of remote sensing of biodiversity in Europe, Mission 2 of Activity 3 of the ARCH project will critically analyse these experiences, in terms of methodology, technologies, skills, service provision and the financial resources used. This Report is the result of collaboration between SIRS and EURISY.

EURISY and SIRS jointly identified and focused on three examples of good practice: one in the Piedmont region of Italy, one in Wales and one in the State of Brandenburg in Germany. These three examples of good practice represent three strategic choices and different models of use, specific to the individual organisational structure of each region.

This report provides a detailed description of each of these different examples. In order to do this, the different elements needed to understand the general framework of each instance of good practice were reviewed, as was the associated satellite service used. This review provided information on the needs and objectives at the heart of each project, the interactions between the different stakeholders, the human and financial resources involved, the size of the area studied, the characteristics of the remote sensing data used, the computer systems and software used or the methodology used for extracting information, the species mapped and the results obtained.

The European experiences detailed in this report will almost certainly not provide answers to all of the expectations and needs expressed so far in the ARCH project, but they should feed into a discussion of and reflection on the potential uses of satellite information for mapping and monitoring habitats and biodiversity, both in technical and organisational terms. These different examples of good practice also have the advantage of being fully operational now. They provide lessons and approaches which could potentially be applied to the ARCH project and the Nord-PasdeCalais and Kent regions.

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List of abbreviations

AGEA	Agenzia per le Erogazioni in Agricoltura (Italian Ministry for Agriculture)
ARCH	Assessing Regional Changes to Habitats
ASTER	Advanced Spaceborne Thermal Emission and Reflectance Radiometer
CCW	Countryside Council of Wales
CNES	Centre National d'Etudes Spatiales (National Centre for Space Studies)
CORINE	Coordination of environmental information
CSI Piemonte	Consorzio per il Sistema Informativo Piemonte (Consortium for the Piedmont Information System)
BNSC	British National Space Centre
DEFRA	Department for Environment, Food and Rural Affairs
GMES	Global Monitoring for Environment and Security
GPS	Global Positionning System
HRV	High Resolution Visible
HSV	Hue-Saturation-Value
INBO	Instituut voor Natuur – en Bosonderzoek (Research Institute for Nature and Forests)
IPLA	Istituto per le Piante da Legno e l'Ambiente (Institute for Woods and the Environment)
IRS-LISS	Indian Remote Sensing Satellite - Linear Imaging and Self Scanning sensor
LPIS	Land Parcel Information System
LUGV	National Office for the Environment, Health and Consumer Protection
LUP	Luftbild Umwelt Planung
DTM	Digital Terrain Model
NDVI	Normalized Difference Vegetation Index
NPdC	Nord-Pas de Calais
CAPI	Computer Assisted Photo Interpretation
GIS	Geographic Information System
SIRS	Systèmes d'Information à Référence Spatiale (Spatial Reference Information Systems)
SPOT	Satellite pour l'observation de la Terre (Satellite for Observing Earth)
VHR	Very
UKSA	United Kingdom Space Agency
VITO	Institut Flamand de Recherche Technologique (Flemish Technological Research Institute)

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Introduction

Beyond merely providing an inventory of significant experience and good practice carried out in the field of remote sensing of biodiversity in Europe, Mission 2 of Activity 3 of the ARCH project will critically analyse these experiences, in terms of methodology, technologies, skills, service provision and the financial resources used. This Report is the result of collaboration between SIRS and EURISY.

It is necessary to clarify what is meant by 'good practice'. It is the operational use of a service by decision-makers and managers within one or several public bodies, at a local or regional level comparable to the Nord-Pas de Calais and Kent regions (in terms of the organisational structure of the body), which uses (either totally or partially) satellite information in the fields of natural habitat monitoring and biodiversity. The remote sensing must be used operationally by the body (i.e. not as an experiment), for the practical management of biodiversity. As such, research and development projects were not included in this study.

EURISY and SIRS jointly identified and focused on three examples of good practice: one in the Piedmont region of Italy, one in Wales and one in the State of Brandenburg in Germany. These projects are detailed on a list provided by Jeroen Vanden Borre (INBO) of all the European projects using remote sensing for mapping the Natura 2000 habitats and brought to the attention of the European Commission (DG Environment) (see Annex 1). These three examples of good practice represent three strategic choices and different models of use specific to the organisational structure of each individual region, namely:

- In the Piedmont region example: a decentralised approach to updating the target area, depending on the specific operational needs, either by the region itself and/or by external stakeholders (the operational administrative authorities) who have been trained to use satellite information for mapping habitats in accordance with the common standards specified by the Region.

- In the case of Wales: a centralised approach by a regional public body responsible for protecting biodiversity (the CCW), which enabled the habitat map for the whole of the country to be updated. The habitat map is owned by the CCW and is adapted to its needs. Other regional stakeholders can access the map on request. The regional public authorities are looking at the possibility of sharing the different spatial information held by the different biodiversity stakeholders, and sharing access to the updated map.

- In the Brandenburg example: a centralised approach focusing on producing an inventory of one specific class of habitat (Dry Heaths, Biotope 4030 in the Natura 2000 nomenclature). In this specific case, the use of satellite images represents the most appropriate way to collect the level of detail required, and the least expensive and quickest way to map well-defined zones, which are off-limits for security reasons.

This report provides a detailed description of each of these different examples. In order to do this, the different elements needed to understand the general framework of each example of good practice were reviewed, as was the associated satellite service used. This review provided information on the needs and objectives at the heart of each project, the interactions between the different stakeholders, the human and financial resources involved, the size of the area studied, the characteristics of the remote sensing data used, the computer systems and software used or the methodology used for extracting information, the species mapped and the results obtained.

The EURISY analysis focused on the organisational and economic aspects of each of the examples of good practice, in terms of the role of the user, formulating the needs, the organisation of and interactions between the different users, service providers and beneficiaries, and the economic viability of the service. As SIRS has expertise as a service provider in the field, it carried out the detailed analysis of the technology used by each region in terms of choosing the methodology developed by the region, the data used, the cartographic results and the technical feasibility and transferability.

The European experiences detailed in this report will almost certainly not provide answers to all of the expectations and needs expressed so far in the ARCH project, but they should feed into a discussion of, and a reflection on, the potential uses of satellite information for mapping and monitoring habitats and biodiversity, both in technical and organisational terms. These different examples of good practice also have the advantage of being fully operational now. They provide lessons and approaches which could potentially be applied to the ARCH project and the Nord-PasdeCalais and Kent regions.

In order to carry out this Mission successfully, many conversations took place by telephone and email, and meetings were organised with the following principal members of staff and professionals involved in the good practice (the project managers and technicians):

Wales - EURISY met with the following professionals:
Alan Brown - Remote Sensing Manager, Countryside Council for Wales
Katie Medcalf - Environment Director, *Environment Systems Ltd*, Aberystwyth, Wales
Ian Thomas - independent Consultant, *Sector facilitator Environment SectorUKSA* (*UK Space Agency*)

Piedmont region - EURISY and SIRS met with the following professionals:
Susanna Pia - Director of the Office for Protected Areas
Chantal Diegoli - *CSI Piemonte*
Fabio Gianetti – Head of the Remote Sensing Laboratory, IPLA

Federal State of Brandenburg - EURISY met with the following professionals:
Martina Düvel – Responsible for Coordination, Northern Natural Parks, the Regional Office for the Environment, Health and Consumer Protection, Brandenburg, Germany
Antje Koch-Lehker – Responsible for Natura2000, the Regional Office for the Environment, Health and Consumer Protection, Brandenburg, Germany
Dr. Frank Zimmermann – Responsible for Natura2000, the Regional Office for the Environment, Health and Consumer Protection, Brandenburg, Germany
Dr. Annett Frick - LUP *Luftbild Umwelt Planung GmbH*, Potsdam, Germany

In addition, the following exchanges of experience and expertise also took place:

- Meetings with habitat monitoring professionals in France and Europe. SIRS was also able to meet with Flemish habitat professionals, specifically with INBO (the Research Institute for Nature and Forests) and VITO (Flemish Technological Research Institute) (see Annex 2). They were:
    - Birgen Haest - Scientist, VITO
    - Desiré Paelinckx – Responsible for the Research Team, INBO
    - Gerald Louette - Scientist, INBO
    - Toon Spanhove - Scientist, INBO
    - Jeroen Vanden Borre - Scientist, INBO

- Participation in European workshops on habitat monitoring such as the HABISTAT workshop which took place in Brussels on 13 October 2010, attended by both SIRS and EURISY (see Annex 3: summary of the Habistat workshop);
- Bibliographical research and literature review of scientific articles.

1. Good practice in the Italian Piedmont region: "Mapping protected areas in Piedmont using satellite information"

1.1. Organisation: structure, mission and objectives

The system of protected areas in Piedmont comprises the following:

*	Number of sites	Hectares	% of land
Protected areas	69	218,171.98	8.59
Natura 2000 sites	142	396,797.78	15.62
Sites of regional interest	41	15,764.09	0.62

Source: http://www.regione.piemonte.it/sit/argomenti/parchi/index.htm

The Office for Planning and Management of Protected Areas (Office for Protected Areas) is a service of the Department for the Environment for the Piedmont region. It implements regional, national and European recommendations concerning protected areas. In particular, it is responsible for:

– developing management plans for the protected areas;
– coordinating the scientific committee which supports the regional policy on protected areas;
– providing technical and scientific assistance to the 38 organisations managing the protected areas;
– managing the biotopes and biodiversity;
– providing information and marketing.

In carrying out its remit, the Office for Protected Areas cooperates with other stakeholders, such as:

The Institute for Woods and the Environment (or its Italian abbreviation IPLA) is a private company comprising 80% public capital from the Piedmont region and 20% capital from public administrations. The IPLA works exclusively with the public bodies which finance it. It is a unique resource in terms of technical expertise and assistance in the forestry, environment, energy and remote sensing fields. It is currently responsible for developing the management plans for protected areas for the Office for Protected Areas and for providing assistance to the organisations managing protected areas.

The IPLA teams involved in the management projects include five or six multi-disciplined specialists (in remote sensing, mapping, fauna, forests and flora). Other specialists, for example ornithologists, can be involved if required.

CSI Piedmont is a private company funded with public capital by the Piedmont region. The company is responsible for the regional information system. Its varied skills in Information Technology are applied to all the areas of public intervention: the environment, land planning, health, etc. Out of around 1,000 employees, 100 work exclusively on the environment and land use planning.

38 local administrative organisations have autonomous jurisdiction over specific geographical areas, where the protected areas can be found.

The Po Park Authorityis an example of a management organisation. It is one of the users of satellite data. The park has two areas of responsibility:

1. The technical office for monitoring and managing protected areas has:
   - a mapping specialist;
   - a forestry technician;
   - an urban planner;
   - a specialist in fauna.

2. Monitoring and enforcement of the law: 8 employees (Park Wardens).

The expertise of external collaborators is called upon depending on the skills required.

1.2. Challenges

The Office for Protected Areas does not have the resources or the responsibility to operationally map in detail, and manage, the whole of the protected areas. In addition, the Office for Protected Areas considers that the local administrative organisations are often better able to manage the areas placed under their jurisdiction.

That said, as one of the roles of the Office for Protected Areas is to coordinate the management of protected areas, it has had to develop a strategy to ensure that the protected sites are mapped and effectively protected in accordance with the best criteria, and in an integrated way (e.g. shared criteria).

In addition, since the adoption of a regional law in 2006 on biodiversity and protected areas, the Office for Protected Areas has had the legal obligation to produce management plans for these areas. Amongst others, the plans define the conservation objectives and detail how they will be met and measured by the organisations responsible.

1.3. Introduction and use of satellite information systems

The Office for Protected Areas took the strategic decision to allow the local administrative organisations (e.g. park authorities, towns and smaller administrative units) to directly and autonomously use satellite information in order to be able to manage protected areas more effectively on the ground, whilst also adopting an overall integrated view of the land.

Several stages were required to ensure that these users were fully operational:

Implementation: stage 1 (1995-2005)

The Office for Protected Areas encouraged the general use of computer tools and geographic information by local administrative bodies by:

- training the users to use the data;
- disseminating the data;
- introducing IT reference standards;
- testing the satellite technologies through pilot projects, specifically the project involving the Po River National Park. This pilot project called for Very High Resolution spatial satellite images.

Following this work, a manual for photo interpretation was produced containing information on how to interpret and use satellite data operationally.

Implementation: stage 2 (2004-2006) - Alcotra Interreg Project

The principal aim of this project was to define a common approach and methodology for mapping habitats in accordance with the CORINE Biotopes nomenclature of Natura 2000 sites, which could then be transferable to the management bodies in the Piedmont region.

The methodology being used today originates from the Interreg Alcotra project, as does the *Technical Manual for Drafting Natura 2000 site management plans*, which presents standards for habitat mapping.

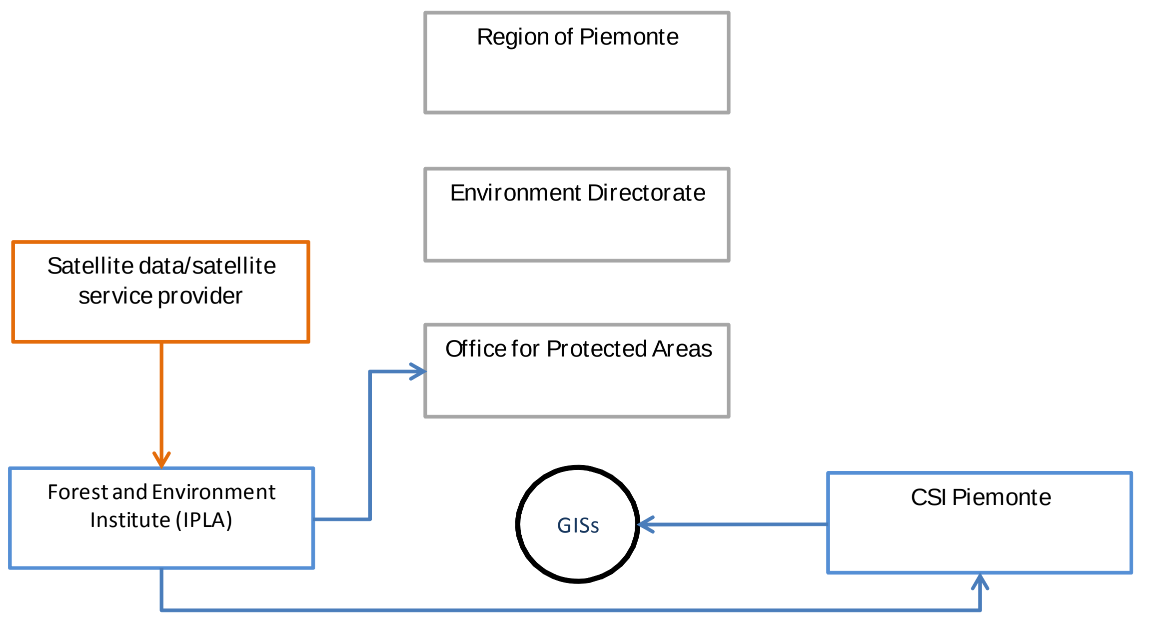
Operational stage:
Today nearly 80% of the bodies managing protected areas in the Piedmont region use GIS systems, even if only to check essential information on thematic maps. 50% of these organisations use GIS in more detail for managing protected areas, including using information derived from remote sensing. The methodology for processing satellite data developed as part of the Alcotra Interreg project has been adapted to the technical skills and role of the management bodies by simplifying the original method (i.e. the one presented in the manual).

1.4. Interaction and dissemination of information

1.4.1. The Office for Protected Areas as a user of satellite information

The law requires the Office for Protected Areas to produce management plans for the protected areas. The Office entrusts the production of these plans, based on the habitat maps, to the IPLA.

The IPLA buys the satellite images on behalf of the Piedmont region (when the funds are available). Once the IPLA has processed and exploited the satellite data and produced the management plans, the maps are sent to the CSI Piedmont which then integrates them into the relevant information systems so that they can be used as a reference for end users.



IPLA purchases satellite data, interprets it and provides site management plans to OPA.
CSI Piemonte integrates the resulting maps in relevant information systems

Figure 1: Interaction between the IPLA and the service providers (IPLA and CSI Piedmont)

Once the management plans have been approved by the Office for Protected Areas, they become compulsory for all the bodies managing natural areas, including parks.

The information obtained from the maps enables the Office for Protected Areas to guide the regional policy in this field.

1.4.2. Local administrative bodies as end users: example of the Po Park Authority

The Po Park Authority has greater operational responsibilities in relation to the geographical area it is responsible for. This area includes the protected areas. Through its involvement in the pilot projects, the Po Park Authority was amongst one of the first administrative bodies to autonomously exploit the data obtained using remote sensing.

Although the Park uses the data and maps produced by the Office for Protected Areas to a certain extent, not all the maps available are necessarily adapted to the specific management needs of the Park. Consequently, the Park also buys, interprets and uses satellite and aerial data which it exchanges with the Office for Protected Areas (see figure below).

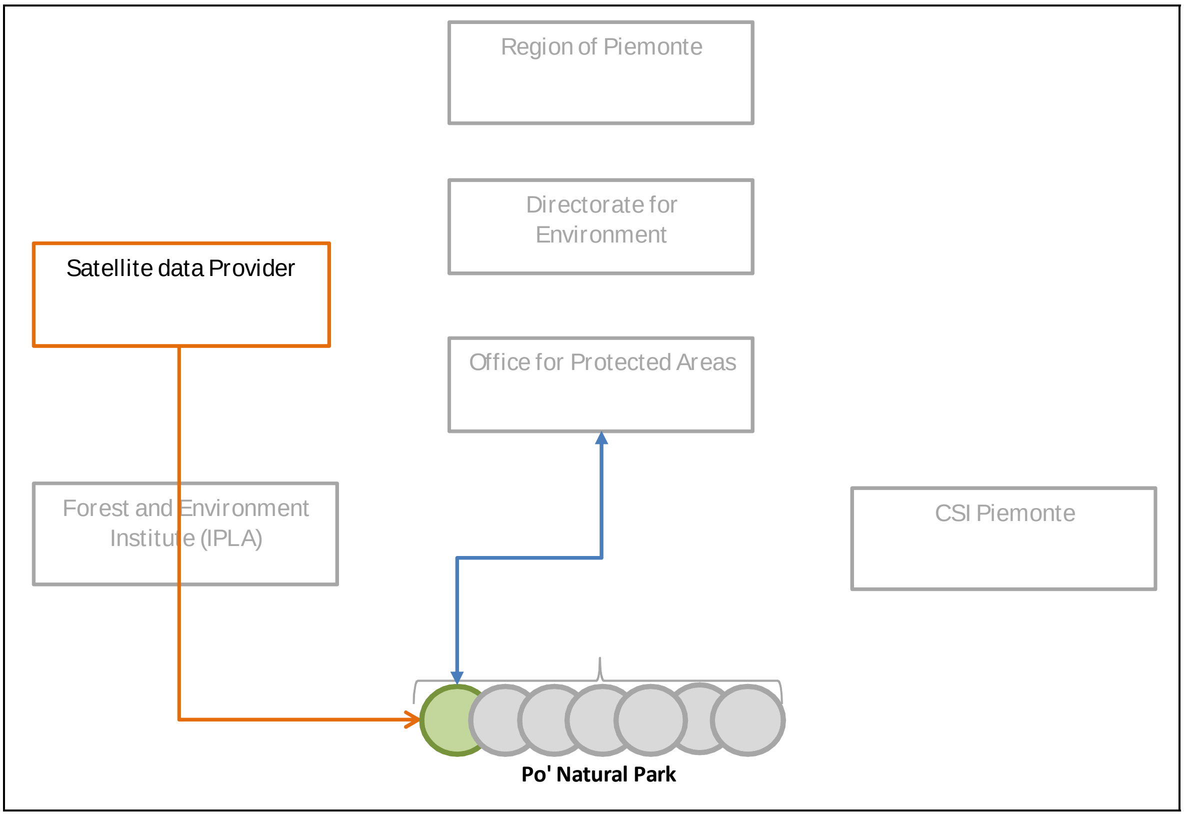


Figure 2: The Po Park Authority acts autonomously in acquiring and using satellite data

The Park uses satellite and aerial imagery, and endeavours to share the data with other authorities. The data obtained from remote sensing, whether satellite or aerial, is always complemented by field surveys carried out by park personnel.

1.5. Methodology for interpreting data obtained from remote sensing[1]

1.5.1. The approach used for extracting information

The Interreg IIIA Alcotra project enabled the Piedmont region and the Office for Protected Areas to establish a methodology for mapping and monitoring habitats (in accordance with the nomenclature of the CORINE Biotopes and Natura 2000). This methodology proved to be cost-effective, repeatable and transferable to the organisations responsible for managing the protected areas so that they can implement the management plans. The specifications for using the methodology are detailed in the manual mentioned above (*Technical manual for drafting Natura 2000 site management plans*). However, the method was adapted by the IPLA, whilst respecting the original specifications for use, in order to make it fully operational for the management organisations.

The habitat mapping approach which was kept is a floristic approach, correlated to the remote sensing information in order to facilitate habitat mapping. The approach is based on integrating remote sensing and aerial data to delimit polygons with exogenous and terrain data to determine the thematic information. In the end, the scale of the habitat maps produced is 1:10000.

1.5.2. Data

For mapping natural habitats, the use of satellite data is recommended. Satellite imagery is therefore preferred compared with aerial photography or ortho-aerial photography which is used as supportive data or when satellite data is missing.

During the development stage before production, an estimate of the costs and benefits for using satellite imagery was made. The observation that Very High Resolution imagery is a satisfactory alternative to aerial photography was therefore put forward. More precisely, satellite images with spatial resolutions of around 0.5 to 3 metres were identified. Data such as this is an excellent alternative to aerial data, both from a financial and a technical point of view. Furthermore, and more precisely, the satellite data identified must have, from amongst the different multi-spectral bands, a near-infrared band. This near-infrared band provides a great advantage for discriminating different plant communities.

[1] GIANNETTI, F. and CANAVESIO, A. Metodologia per la cartografia degli habitat, Allegato 8. Alcotra, Progretto Interreg IIIA.

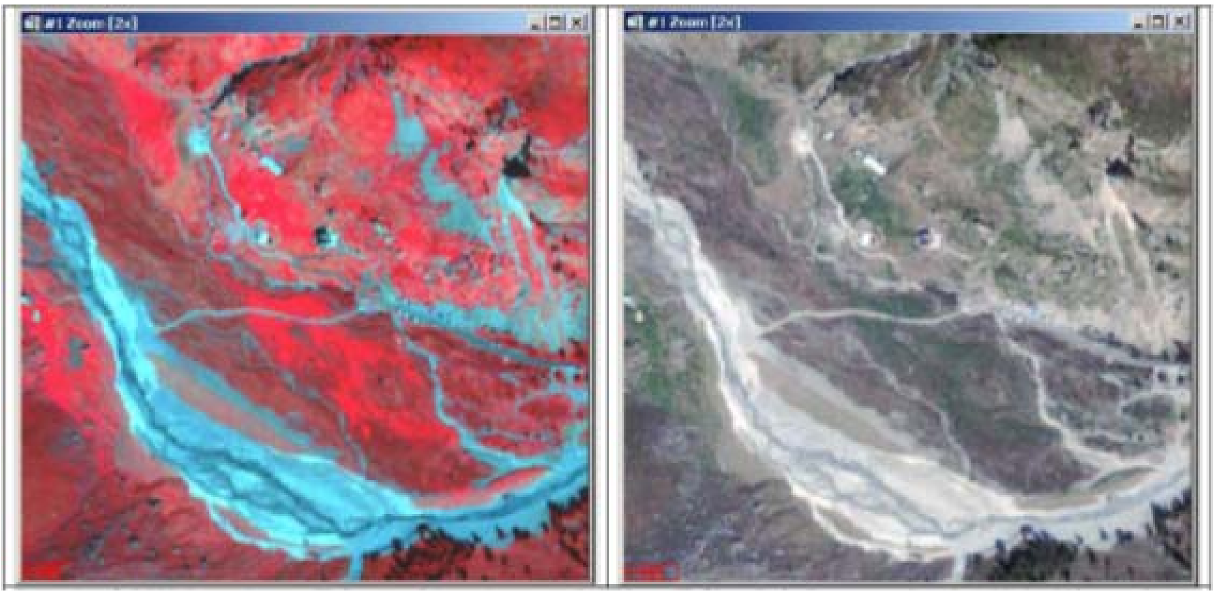


Figure 3: The advantage of infrared spectrum (compositions shown in false-colour and pseudo-colour)

Figure 4: Comparison between an ortho-photograph (left) and the panchromatic band from the QuickBird satellite (right)

For example, for the Interreg IIIA Alcotra project, a series of satellite images from three sensors were obtained, namely QuickBird, Ikonos and SPOT. The QuickBird-2 data has a spatial resolution of 2.8 metres and a spectral range covering 450 – 900 nm (4 bands). The Ikonos-2 images have a spatial resolution of 4 metres and a spectral range covering 450-900 nm (4 bands). Lastly, the SPOT-5 data has a spatial resolution of 10 metres and a spectral range covering 500 – 1750 nm (4 bands). For the first two sources of data, the panchromatic information is still accessible (at 0.7 and 1 metre spatial resolution respectively). Therefore, it is possible to develop images at an improved spatial resolution, called "pan-sharpened" images. Furthermore, the majority of these satellite images were acquired especially for the project. The others came from the archives of the producers of the data.

However, the use of satellite data on its own is not sufficient. It is possible to supplement Very High Resolution satellite images with ortho-photographs. As part of the Alcotra project, aerial data from the Ministry for Agriculture (AGEA) was used. Depending on the situation, this data came to be used to support the cartography. Nevertheless, most of work is carried out using satellite images.

1.5.3. Data pre-processing

Once acquired, satellite images must undergo a series of pre-processing measures in order to be able to be manipulated. The usual geometric corrections are carried out and the satellite images are geo-referenced as is required in the drafting of maps with scales of between 1:10000 and 1:25000.

Next the “pan-sharpened” images are produced. This involves improving the resolution obtained by merging the panchromatic data from the satellite image with the multi-spectral data. This fusion is carried out using the HSV (Hue Saturation Value) transformation. As part of the Interreg project, false-colour images of 0.7 and 1 metre resolution were obtained for the QuickBird-2 and the Ikonos-2 data, respectively.

Figure 5: Fused image (“pan-sharpened”)

1.5.4. Extracting information

The first interpretation of satellite data (coupled with the exogenous data) could then be carried out. The Interreg IIIA project resulted in an approach using Computer Assisted Photo Interpretation (CAPI). This methodology was preferred to an object-oriented classification approach. The work carried out in parallel by the IPLA enabled the object-oriented classification to be tested. However, it did not provide satisfactory results. In actuality, the use of one date data does not enable this approach to be fully exploited.

	a		b		c		d		e	
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA
Prati	57.14	61.54	57.14	57.14	35.71	100.00	42.86	100.00	69.23	56.25
Querceti	42.27	50.62	41.24	50.63	36.08	52.24	39.18	53.52	34.74	54.10
Acero-Tiglio-Frassineti	3.57	11.11	3.57	11.11	10.71	23.08	7.14	15.38	14.81	13.33
Castagneti	53.85	18.42	50.00	16.88	42.31	14.67	57.69	19.48	37.50	19.15
Rimboschimenti di conifere	33.33	50.00	33.33	50.00	66.67	31.58	55.56	33.33	33.33	37.50
Robinieti	13.89	17.86	16.67	20.69	13.89	17.86	18.92	26.92	26.47	19.57
Zone urbanizzate	55.56	83.33	44.44	80.00	100.00	75.00	100.00	75.00	33.33	100.00
OA	35.16		34.25		33.79		37.27		33.18	

Figure 6: Accuracy (producer and user) obtained during object-oriented classification tests on habitats

The images are photo-interpreted on a GIS platform at 1:10000 (currently using the ArcView 3 environment, ArcGIS is recommended for the future). The CAPI work aims to establish the polygon limits of the entities visible on the images. This work is carried out in collaboration with experts in botany and remote sensing. The joint use of the infrared channel and the DTM enables specific habitats to be detected. In particular, the DTM enables the aspect and slope of the land to be estimated. This data is very important for identifying the spatial distribution of habitats.

In the end, the photo-interpretation, carried out using multi-disciplinary expert knowledge and a set of exogenous data, enabled the first layer of polygons, based principally on the spectral information and the differences in texture between the objects, to be produced.

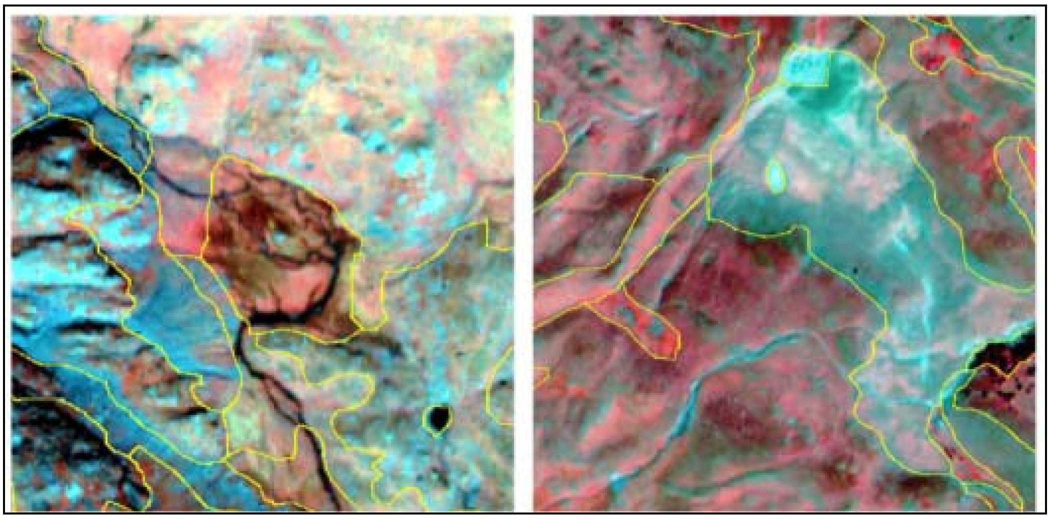


Figure 7: Example of the delimitation of polygons on satellite images

Next, in the second phase, the field work is undertaken. The field work should enable each polygon identified previously to be classified. The field work therefore enables the floristic and phytosociological information on the habitats(s) associated with each polygon to be extracted, thus enabling the key habitats and species to be identified. This involves determining the content of each polygon. It is important to note that within one polygon, different habitats can be identified with regard to the physiognomic characteristics and delimitation of the cartographic units (a maximum of three habitats). Notes are then taken, describing the habitat composition and the percentage of cover. Each point taken on the ground and geo-referenced by GPS, can then be imported into the GIS platform in order to be included in the database associated to the objects. Furthermore, across the terrain, the geometry of the polygons can be checked and changes can then be made.

Following the field work, the definitive list of habitats for each polygon is drawn up. The maps can then be produced. The scale of the maps is 1:10000. Each map is then assembled (or not) to form one single map. The legend information and graphical aspects are also defined. Furthermore, each map produced undergoes a final check in terms of verifying the geometry of the polygons and the themes.

In the Alcotra project, the preparation of the joint maps for the two regions, also required a common nomenclature for defining the habitats (still based on the CORINE Biotope nomenclature) and also for the same legends to be used by both regions.

In the future, updates every 2-3 years are recommended for analysing changes and developments within each entity and associated protected area. Updates every 10 years for deeper analysis of the habitats are expected.

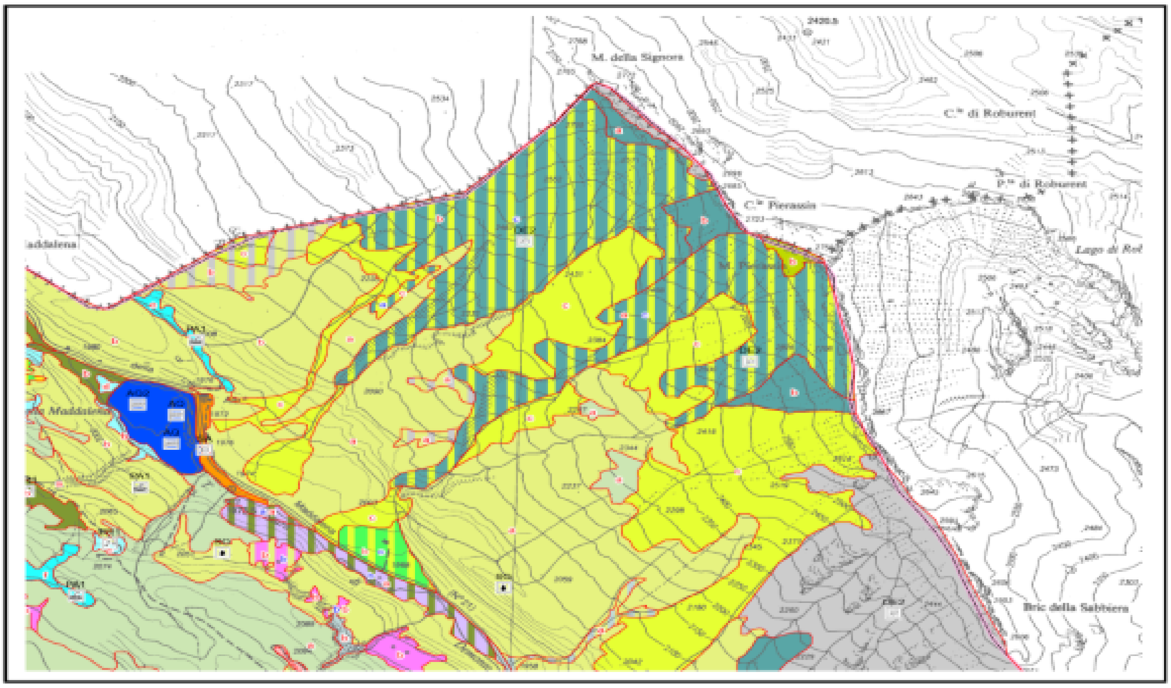


Figure 8: Example of a representation of a habitat map superimposed onto a topographical background obtained during the Alcotra project

1.6. Resources used

The Office of Protected Areas bought satellite images at a cost of €20,000-28,000. Some of these images were bought by the Department for Agriculture.

The IPLA has a budget of €1.5 million to produce the Management Plans and the maps.

The Po Park Authority bought its satellite images of an area covering 800 km² and 90 km long (along the Po River) from the intermediary Planetek Italia in 2007 at an approximate cost of €15,000 – 16,000.

It should be noted that these figures are only rough estimates. The costs in detail are to be evaluated on a case-by-case basis.

1.7. Conclusions and lessons learned

The commissioning and use of satellite data in the Piedmont region was fuelled by the need for joint electronic databases and maps, and common standards for managing biodiversity, as well as the strategic desire to explore the innovations presented by new technologies such as remote sensing.

The long implementation process led by the Office for Protected Areas enabled 50% of the local administrative bodies to use satellite data autonomously and operationally for mapping habitats and managing the protected areas placed under their jurisdiction. The introduction of data sharing amongst the stakeholders was another great success.

Some aspects of the experiences gained are transferable; others apply quite specifically to the regional organisational arrangements in Piedmont. The following is a list of some of the conclusions from the Office for Protected Areas and the IPLA:

1. A global approach to the territory should not exclude the local dimension.

The Office for Protected Areas arrived at the conclusion that the good management of these areas depended on the involvement of local administrations from the start of the implementation process. The efforts to train users in the local administrations, the introduction of criteria and the dissemination of data all increased the overall level of the management of protected areas in the Piedmont region.

2. The IPLA, an independent and neutral source for multi-disciplined expertise, was crucial to the success of the project.

The IPLA still assists the Office for Protected Areas and the local administrations in continually improving their managerial practices.

3. Satellite information is of use to the Piedmont region.

According to the responses of the different people interviewed (the Office for Protected Areas, the IPLA and the Po Park Authority), satellite images are particularly relevant to regional authorities such as the Piedmont region because they enable reliable and repeatable methods to be used to monitor changes at the level of the protected areas. The use of this data enables cost savings, particularly when their purchase and use is shared by several different types of users (e.g. the Department for Agriculture, the Department for Land Use Planning and the Department for the Environment). The use of satellite information to guide site visits in areas where significant changes have been observed enables both cost and time savings for the authority responsible.

According to the Po Park Authority, in terms of cost it makes more sense to buy satellite data rather than aerial photographs for the updates, unless such data is available free of charge.

Furthermore, the methodology established by the Piedmont region and the Office for Protected Areas enabled different expectations and objectives to be met:

- Delimiting and mapping habitats and plant communities with a greater degree of precision. This is possible by integrating the data from the field work for the thematic information with the interpretation of Very High Resolution satellite data for the geometric information. The use of near-infrared spectral information produces a particularly a clear and detailed map of the different plant communities.
- Classifying these habitats using the references of the CORINE Biotopes and Natura 2000 nomenclatures, made possible by the field work phase and the compilation of the habitats list. In the ARCH project, the field work is only carried out during the validation phase, with the CAPI enabling the polygons to be cut and the associated habitat to be classified. In this case, the satellite image is only used to establish the geometry of the polygons and not the thematic content.
- Producing habitat maps which can be used effectively for management measures by the different administrations, at all levels (e.g. at site, regional and national levels).
- By combining the physiognomic and floristic approaches, the resulting cartographic units could be easily identified and used for management purposes.

However, this approach does have some limits:

- The methodology presented was only used at the level of the protected areas and sites in the Piedmont region by local authorities and not at a global level by the central body. As such, this approach is perhaps not possible for an entire region such as Nord-Pas de Calais or Kent and could not be carried out by one single body. This approach requires a large amount of field work. As in the Piedmont region, a management body based approach is preferable. In addition, consistency should be ensured by a guide which proposes the specifications to be followed.
- The approach requires a lot of work on amalgamating the vectoral database.

4. It is important to share the use of existing data and to centralise buying new data in the future in order to reduce costs.

The Office for Protected Areas and the local administrations all try to share and re-use the data as much as possible (for example, by using the data from other departments, such as the Department for Agriculture).

In the future, the Region plans to:
- entrust the purchasing of data to one regional organisation;
- reference the data in one “central catalogue”;
- make the data available to other administrations.

5. In terms of data sharing, it is essential that multi-licenses are obtained for the images.

The Office for Protected Areas was confronted with the problem of the number of licences time and time again; consequently it is a central concern when acquiring new data.

2. Good practice in Wales: "updating the habitat map of Wales using information derived from satellite data – Countryside Council for Wales"

The *Countryside Council for Wales* (CCW) is the Welsh consultative body responsible for nature conservation, protecting biodiversity and ensuring permanent public access to the natural heritage of Wales. It is essential to have recent maps of the countryside and habitats in order to be able to manage the health, integrity and the natural beauty of the Welsh landscape, which is amongst the country's most important assets, and also to limit the negative effects of urbanisation, agriculture, tourism and climate change.

2.1. Organisation: structure, mission and objectives

Protected sites represent about 30% of the Welsh land and coastline. They include three national parks, five *Areas of Outstanding Natural Beauty* (AONB), more than a thousand *Sites of Special Scientific Interest* (SSSIs), twenty *Special Protection Areas* (SPAs) and ninety-two *Special Areas of Conservation* (SACs).

The CCW is an official consultative body under the authority of the Welsh National Assembly. The Welsh Assembly appoints the members of the Council and provides its annual budget. It employs 500 people and has offices throughout Wales.

The CCW comprises two directorate and three regional offices:

The Evidence and Advice Directorate is responsible for the development and implementation of the CCW's strategies. It is also responsible for assisting the CCW in providing technical and scientific advice and has an advisory role to the Welsh Government.

The Planning and Resources Directorate includes business planning and grant management, as well as all the technical assistance services, including the GIS Unit.

The three regional offices (north, west and south-east) are the local interfaces with land owners, local authorities and the public in general for questions related to planning and conservation, as well as queries concerning biodiversity in general.

The CCW's remit covers three main areas of activity:

- nature conservation: national protected sites, international protected sites (Natura 2000, the Ramsar Convention- the Convention on Wetlands), examining planning applications;
- combining public access to the countryside with nature conservation: for example, by identifying routes with local authorities for public footpaths;
- advising the Welsh Government on questions related to maintaining the landscape (environmental risks, national and international legislation, land use and its impact on habitats and species).

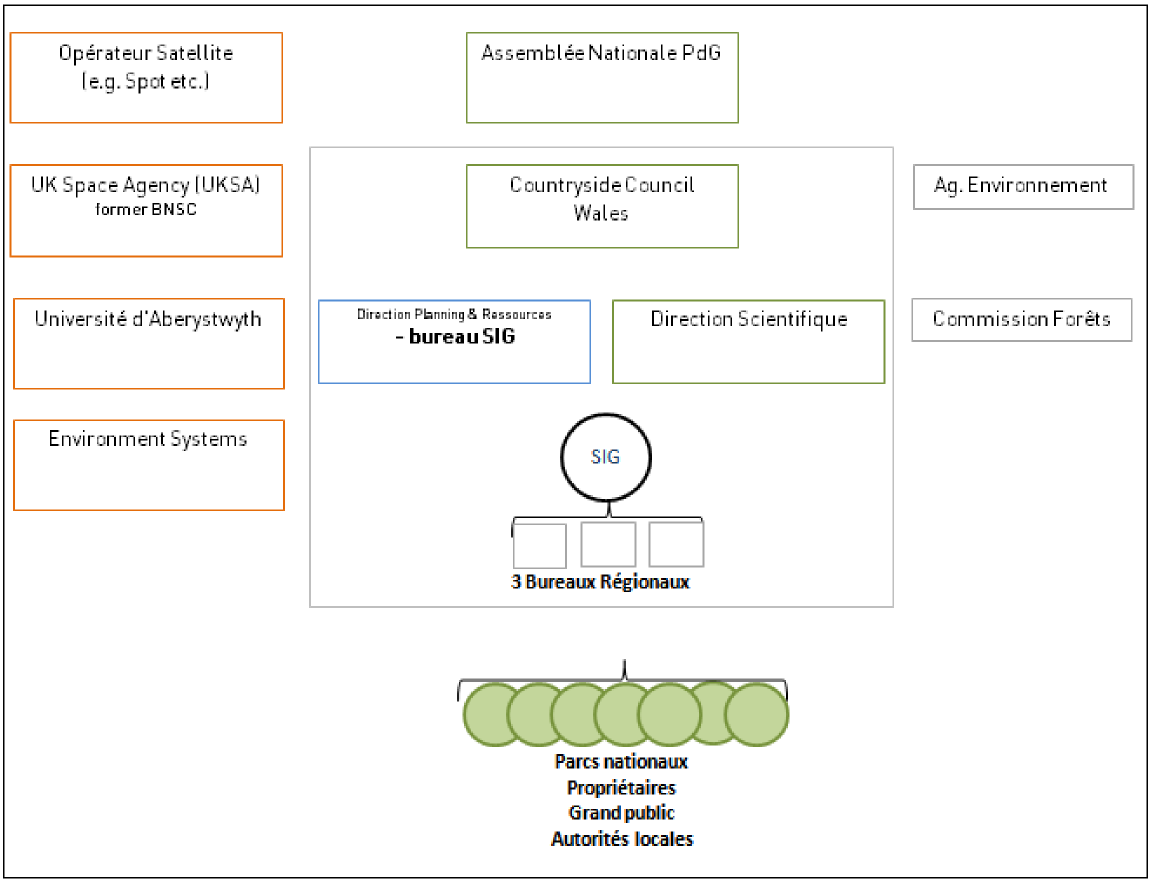


Figure 9: Organisational structure of the CCW

The CCW cooperates and coordinates its actions with two other public bodies in the field of natural heritage management (both coming under the responsibility of the United Kingdom's Department for the Environment (DEFRA) and the Welsh National Assembly):

The Welsh Environment Agency's mission is to protect the environment and promote sustainable development (regulating the principal industries, agriculture, fisheries, air and water quality, managing flood and coastal risks, and climate change).

The Forestry Commission for Wales is responsible for the promotion and sustainable use of forests.

2.2. Challenges

As landscapes are continually changing (whether by a natural processes or due to human intervention), the CCW requires a means for obtaining precise and recent information on these changes and on the habitats affected in order to be able to achieve its aims as effectively and accurately as possible.

Furthermore, while the focus of biodiversity conservation, which was previously on protecting habitats through protecting the surrounding sites, has moved towards considerations related to the connections between, and the fragmentation of, habitats across the landscape, the existing maps no longer offer the quality of detail required to enable groups of two or three trees to be identified which can act as corridors for certain species.

In 2000, when the *Countryside and Rights of Way* law entered into force, guaranteeing the public right of way through the countryside, it became necessary to have a detailed map of the *Berwyn*

*Mountains*region which showed the public footpaths. This was an opportunity to assess whether remote sensing was the most appropriate and effective method for updating the existing habitat maps, as well as for determining if this approach could be generalised to the whole country.

2.3. Introduction and use of satellite information services

The implementation took place in four distinct phases (2004-today):

Feasibility study: stage 1 – The study looked at the possible benefits of using satellite imagery for updating habitat maps.

Test phase: stage 2 – A successful test was carried out on four geographically and ecologically distinct areas, including the *Berwyn Mountains.*

Updating the existing maps: stage 3 – The updating process involved the habitat map of Wales from the “Phase 1 Habitat Survey”. This first map of semi-natural habitats was created using topographical surveys and aerial photographs. The work began in 1979 on the uplands and finished in 1997 on the lowlands. It was therefore out of date.

Stage 4: integrating the updated map into the CCW information system and its use by CCW personnel.

The decision to use remote sensing was facilitated by the assistance provided by the British National Space Centre (BNSC[2]) to the CCW under the GIFTSS programme (*Government Information from the Space Sector*), which aims to encourage public authority access to information derived from satellite services.

The BNSC co-financed the feasibility study and entered into a contract with the service provider on behalf of the CCW, consequently sharing the inherent risks. From the start of the project, and more specifically during the first two phases, an expert on assisting users of remote sensing was available to provide advice and assistance in evaluating the quality of the bids for the field tests, received by the CCW following an open tender.

[2] The BNSC became the *UK Space Agency* on 1st April 2010.

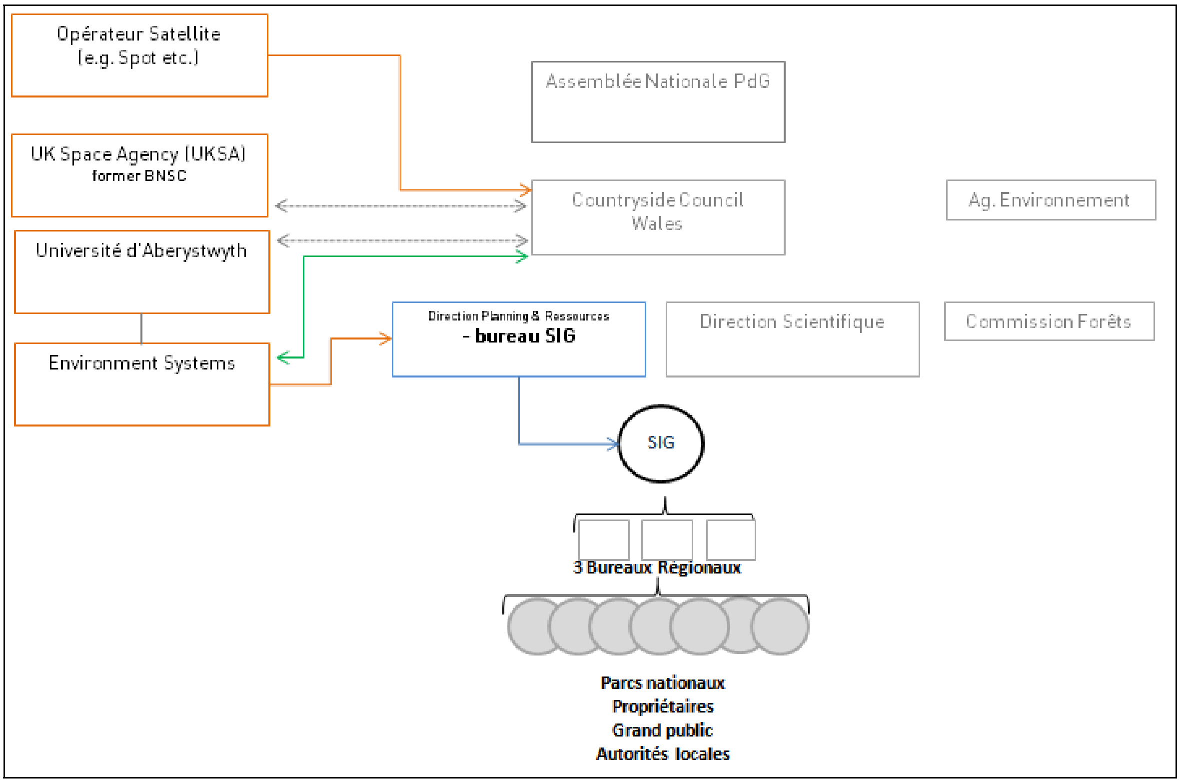


Figure 10: Producing the information (habitat map)

2.4. Interaction and dissemination of information

2.4.1. Producing the information

The CCW buys the raw satellite images with individual licences. Consequently, it is only once the images have been exploited, interpreted and transformed into the habitat map that the information can be shared with other stakeholders (such as local public authorities). This therefore makes data sharing possible and facilitates a collaborative strategic approach for implementing environmental policy.

The service provider Environment *Systems Ltd*[3], with its experience in ecology and nature conservation, won the contract for the field tests, as well as the main contract to update the habitat maps. These contracts included developing the methodology, producing the mosaic and interpreting the images. *Environmental Systems* then sub-contracted part of the work to the University of Aberystwyth (the Remote Sensing Department) because it is highly-skilled in developing and applying a methodology. As a result of the innovative character of the project, the Project Manager at the CCW benefited from the expertise of both the expert at the BNSC and the University of Aberystwyth.

Once the vectoral habitat map (produced using satellite imagery) was created by the service provider, it was then transferred to the CCW where it underwent testing by the end users in the central directorates and the regional offices.

The testing was carried out by comparing the new map with the existing maps and other data, before being sent to the GIS Unit for integrating into the CCW's central GIS system. The CCW's GIS experts all

[3]*Environment Systems Ltd*, based in Aberystwyth, Wales is an off-shoot company set up by the Department for Remote Sensing at the University of Aberystwyth. They both colloborated closely on this project.

have experience in the field of ecology, and with assistance from the Evidence and Advice Directorate they contributed to the quality control.

2.4.2. Using the information

Once the updated habitat map is integrated into the GIS system, it can be used by different types of end users. Internally, the personnel from the Evidence and Advice Directorate use the information on the maps to design and establish long-term strategies aimed at nature conservation, and to advise the Welsh Government. The personnel in the regional offices use the areas on the maps related to their regions to study the possible impact on the landscape of building planning applications and public projects, advising on the measures to be taken and working with land owners to manage protected sites. *Environmental Systems* currently organises training courses for the CCW personnel. Three courses have already taken place with six to eight participants from the regional offices, the central directorates, GIS specialists and end users.

Public bodies such as the organisations managing the national parks, the Forestry Commission and the Environment Agency, for whom access to the updated habitat map could help them in carrying out their remit, can send requests for information to the CCW, either through the regional offices or directly via the GIS Unit. As some stakeholders also hold information in the form of geographic data sets which could be of use to the CCW and other stakeholders in the biodiversity field, the Welsh Government recently launched a public consultation on a potential Natural Environment Framework[4] for Wales which could lead to increased cooperation between the public agencies in terms of sharing the joint data sets.

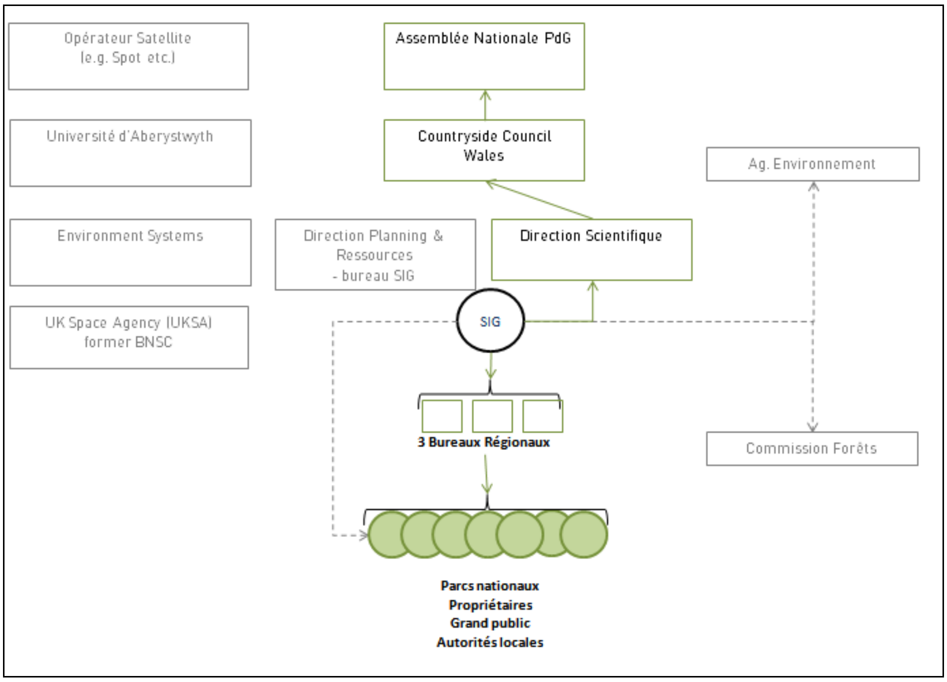


Figure 11: Using the information

[4]http://wales.gov.uk/consultation/desh/2010/100909livingwalescons/100908alivingwalesconsultation?lang=en

2.5. Methodology for interpreting the data obtained from remote sensing[5]

2.5.1. The approach used for extracting information

To reiterate, the methodology developed and presented in this case study for updating the maps of the Welsh territory (around 20,000 km²) comes from Phase 1 which provided the country with its first map of semi-natural habitats.

The object oriented classification approach, based on establishing classification rules, was used. While the usual methods of automatic classification only take account of the spectral information, this approach enables ecological, topographical and contextual knowledge applicable to the remote sensing information, to be taken into consideration.

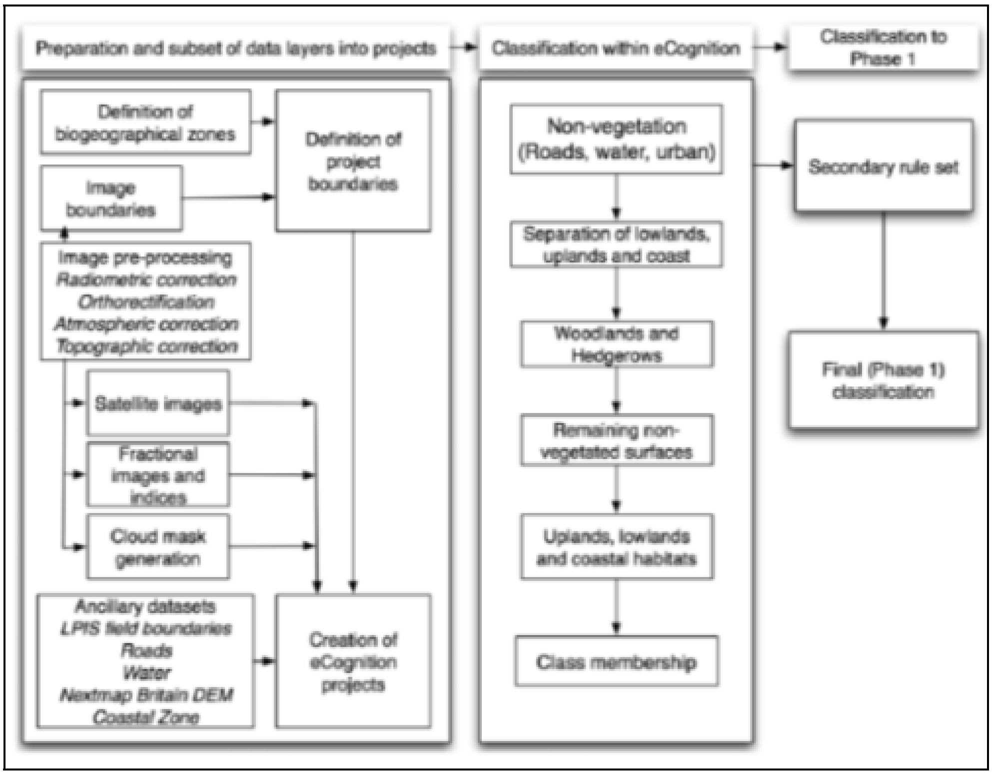


Figure 12 : Diagramme of the methodology used

2.5.2. Data

The previous maps produced in Wales using satellite images were essentially based on Landsat images of 30 metres spatial resolution. However, the use of this data was limited by the medium spatial resolution andthe number of scenesundisturbedbyatmospheric phenomena (e.g. clouds, shadows, etc.), particularly in spring and summer.

Images acquired during these two periods enable better detection of the phenomena related to plant phenology. As a consequence, it was very difficult to acquire sufficient data on these two periods to be

[5] Lucas, R., Medcalf, K., Brown, A., Bunting, P., Breyer, J., Clewley, D., Keyworth, S. and Blackmore, P., 2011, Updating the Phase 1 habitat map of Wales, UK, using satellite sensor data, ISPRS Journal of Photogrammetry and Remote Sensing, 66 (1), pp81-102

able to take into account the seasonal variability of plant communities. To solve this problem, data acquired using optical sensors with higher spatial resolution (of around 10 – 25 m), with a similar spectral resolution, were used.

High spatial Resolution SPOT-5 HRG data was collected for a large part of the country. This data covers the visible portion (400-700 nm) and the infrared portion (1400-2500 nm). The spatial resolution of 10 metres in the visible and infrared portions thus enables a consistent database to be set up with better spatial resolutions than the Landsat data. In the period 2003-2006, 14 scenes were collected, the majority of which were cloudless. The majority of the data was collected during the months of March and September.

In order to best detect the seasonal variability (spectral variability) of plant communities, supplementary information was acquired, namely Terra-1 *Advanced Spaceborne Thermal EmissionandReflectance Radiometer* ASTERdata (with a resolution of 15-30 metres and a spectral range covering 520–11650 nm), and IRS LISS-3 data (with a resolution of 24 metres and a spectral range covering 520–1700 nm). The four IRS scenes were acquired in July 2006, enabling an almost complete cover of Wales to be produced, although some regions were still partially covered by clouds. The ASTER scenes stretching from Swansea Bay in the south to the Berwyn mountains in the north, were acquired between April 2003 and September 2005 (not continuous), covering the spring and the summer. Although some Landsat scenes were available, they were covered in too much cloud. In addition, the spatial resolution was considered to be insufficient for a detailed habitat map, particularly for the lowlands.

In addition, digital aerial photographs and thematic data were produced by the Welsh Government and the CCW to assist the classification process. Thus a complete set of aerial photographs in true colour and infrared (*Vexcel ultracam D* data) with a spatial resolution of 0.4 metres was acquired during the summer of 2006. Aerial photographs covering the whole Wales were also available for 2001. Ecologists' terrain data from the Phase 1 map were also used.

To assist the habitat classification, additional data was also used, particularly a Digital Terrain Model (from NextMap Intermap Digital Terrain Modeldata) with 5 metres spatial resolution, data from the Land Parcel Information System(LPIS), a coastal mask (generated during Phase 1), and OS Mastermapdata and the associated information on water and urban areas. The LPIS data contains the land boundaries for the parcels of land for which the land owners have claimed grants. The maps produced in Phase 2 on the lowlands and uplands were used to assess whether the classification was accurate. As with the map in Phase 1, these maps are based on field work which aimed to delimit and classify plant structures based on the assembly of species (class description in accordance with the National Vegetation Classification (NVC) method). They cover 1079 sites of grasslands, heaths and lowland bogs in the study areas for the whole of Wales. In contrast to the map in Phase 1, this is not a country-level map, but one that is localised to a few sites.

2.5.3. Data pre-processing

Before proceeding with the mapping phase, the satellite data must be pre-processed. Pre-processing chains were applied to the SPOT, ASTER and IRS data, separately for each sensor. The different standard corrections were carried out, specifically the geometric, radiometric, atmospheric and topographical corrections (taking into account the shadows on the satellite images due to the slopes on the terrain, particularly in mountainous areas). The geometric correction was made using the DTM on ENVI and ERDAS Imagine remote sensing software. In addition, each unit of data was re-sampled to 5 metres (pixel size reduced to 5 metres in accordance with the nearest neighbour rule) in order to enable very small objects such as hedges or boundaries between plant communities for example, to be detected. The atmospheric correction was carried out using the FLASH module in the ENVI software. The topographical correction was carried out using ATCOR 3. The atmospheric and topographical corrections enable comparisons to be made between images of a different date, from different sensors and of different regions. However, the use of data from different sensors makes the pre-processing chain much longer.

Next, once the corrections have been carried and the images are ready to be manipulated, the resulting data set is produced. It includes estimates of the relative quantity of humidity/cloud, Photosynthetic Vegetation (PV = active vegetation) and Non-Photosynthetic Vegetation (NPV = dead or senescent vegetation) and the vegetation indices (NVDI). Masks of clouds and shadows were also made using the Definiens software in order to clean the images of atmospheric phenomena.

2.5.4. Extracting the information

2.5.4.1. Dividing the country into biogeographical areas

In order to take into account seasonal and biogeographical variability, Wales was divided into 15 regions each with similar characteristics (similar topography, environmental conditions and habitat distribution according to the map from Phase 1). The 15 regions were then sub-divided into 16 projects and 42 individual sub-projects, following the available scenes captured by SPOT-5 HRG and IRS, and taking into account overlaps with the ASTER scenes. Further sub-division took place during the early stages of the analysis and enabled variability along climatic gradients to be reduced (for example, in the high mountains) and gains to be made in logistic terms when the sub-regions were too large for computer processing. Lastly, SPOT-5 data was available on each project (except for Project No. 9). In addition, regardless of which sensor was used, data for spring and summer was available for each project, except for project no. 5 (two dates in July) and no. 11 (two dates in July and September).

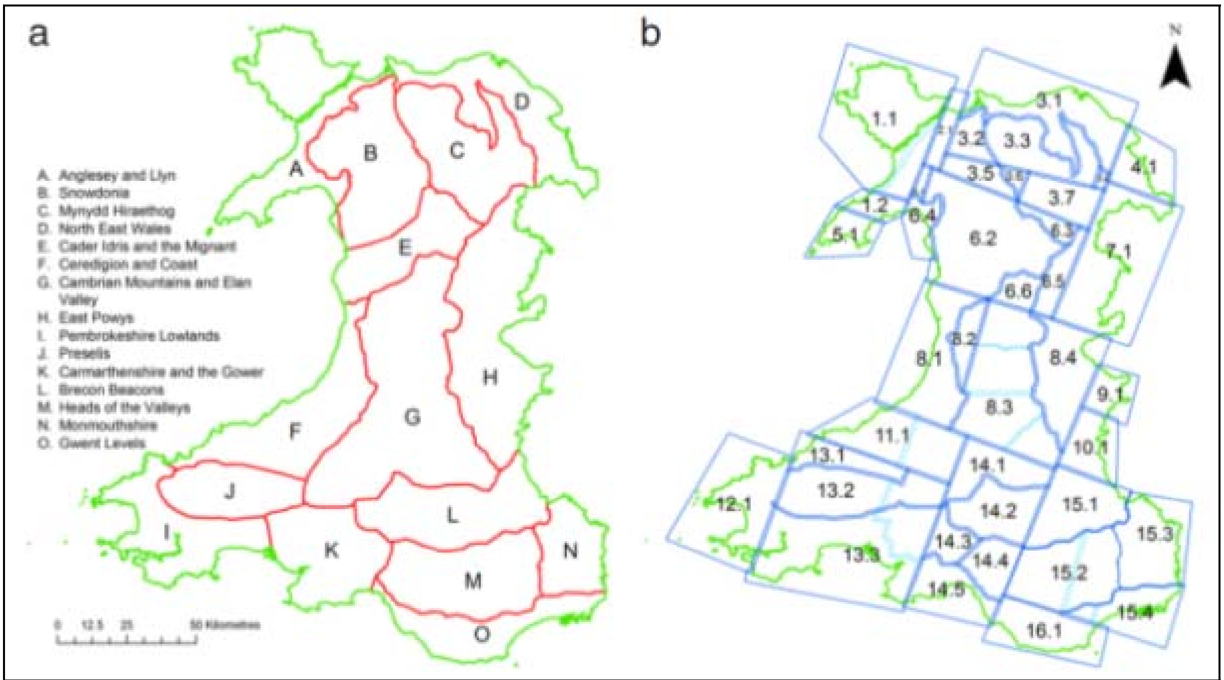


Figure 13: Spatial distribution of the 15 biogeographical zones and the 16 projects and sub-projects

Sensor	Year	Month	Bioregion															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SPOT HRG	2003	Feb		•					•						•	•		
	2003	Mar				•		•		•							•	
	2003	Apr																•
	2003	Sep			•									•	•	•		
	2004	Apr										•						
	2005	Jul	•							•			•		•			
	2005	Sep	•				•	•										
	2006	Nov						•										
Terra-1 ASTER	2003	Apr	•		•			•	•	•	•	•				•	•	
	2003	Jul		•				•		•						•		
	2004	Apr												•				
	2004	May																•
	2005	Jun															•	
	2005	Sep															•	
IRS LISS 3	2005	May															•	
	2006	Jul	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Denotes spring imagery

Figure 14: Distribution of satellite images for the 16 projects (spring is indicated in grey)

2.5.4.2. Segmentation and classification

The first stage of the object oriented classification approach consists of segmenting the satellite image into vectoral objects.

The image segmentation was carried out in several stages. Firstly, the objects situated in urban areas and open waters were generated using OS Mastermapdata and the associated layers. All the remaining areas not classified in the LPIS data were then cut into 1-2 pixel objects taken from the SPOT-5 data (spectral-based). Next, the objects situated outside of the LPIS limits were pre-classified into upland and lowland areas according to the DTM. Within the lowland areas, the coastal areas were removed from the mask obtained during the first mapping exercise (in Phase 1).

Following the initial segmentation and classification (i.e. urban, water, lowlands, mountains and coastal area), two new layers were generated in order to create three new levels of hierarchical layers. Each of these layers was obtained by duplicating the initial layer to be re-segmented to form two additional levels of segmentation, namely a higher level layer (called the *super-level*) and a lower level layer (called the *sub-level*). On the higher layer and within the limits provided by the LPIS, the image was segmented in order to produce one object per LPIS unit (typically a field). For the areas outside of the LPIS, the larger segments were generated using spectral data. At the sub-level, and for the objects outside of LPIS, the image was segmented using a segmentation with a chequered pattern (one pixel per object). The sub-level consists of objects with an initial dimension of 1-2 pixels and was used to classify the sub-habitats. A new segmentation (by fusion) of the objects in the first layer was also undertaken in order to take account of, for example, spectral variability within the large LPIS units, generated in the higher layer.

The use of hierarchical layers in three levels is a characteristic of eCognition (Definiens), enabling variable segmentation of the landscape according to the dimensions, form and homogeneity of the landscape units. The largest objects were created at the higher layer in order to detect the homogenous objects/regions on a relatively large surface (improved arable fields, for example). Next, the size of the objects gradually decreased to the following levels (level 1, then the lower level generally composed of objects of 1-2 pixels) to enable a better description of the most complex habitats in the mosaic (in mountainous and lowland areas, including coastal areas) and sub-habitats.

Hierarchical level	Zone	Example habitats
Super-level	Primarily lowland	Arable
		Improved grasslands
Level 1	Upland/lowland	Woodlands (including felled) and scrub
		Hedgerows
		Urban and water
		Bare ground and rock
	Coastal	Mudflats, sand, saltmarsh
Sub-level	Upland/lowland	Heaths, mires, bogs
		Bracken
		Improved grassland
		Unimproved grasslands
		Semi-improved grasslands
		Flushes and fens
	Coastal	Grasslands
		Heaths
		Dunes

Figure 15 : Habitats classified at each level of the layer

Next, the analysis rules were gradually developed by comparing the ecological knowledge on the habitat and vegetation distribution across the landscape and the content of the information from the remote sensing data. A combination of simple thresholds, Boolean operators (logic) and other rules were used and developed in the eCognition software environment. The values of these different rules were determined using local ecologists' own knowledge of the characteristics of plant species and vegetation communities, based on field observations made during the study. This approach also enables additional topographical and spatial aspects to be taken into account. The rules were developed and tested on the image sub-sets.

The distribution of classes was compared with that observed in the 2006 aerial photographs. All the rules and data used enabled ecological and biophysical considerations to be taken into account, for example, such as the reflectance of different species and stages of growth, photosynthetic activity, the proportion of dead matter, moisture content, surface roughness and slope.

More than 200 rules were developed in accordance with a logical sequence which enabled the habitats in Wales to be mapped, evidenced using rules based on reflectance data, ratios and differences between bands, vegetation indices, behavioural differences between neighbours and seasonal variations. Many of the indices developed were also deemed to be useful for identifying specific habitats (broadleavened woodlands or heaths, for example). Even though the rules used are similar, the values generally vary depending on the images used (ASTER, SPOT HRG or IRS LISS-3) and the date the image was taken. The rules enable variabilities in community behaviour related to the season to be taken into account. Thus, the thresholds used for describing the habitats can be adjusted to the season the images are taken in.

A series of additional rules was developed using eCognition (a set of functions called *Fuzzy membership* functions) in order to process the more complex habitats (sub-habitats) and the objects which weren't classified during the first classification (mainly the heathlands, dune areas and coastal heaths). These rules are also based on spectral data and/or the data derived from it, as well as topographical data depending on the case. These new rules were then applied separately depending on the type of landscape (e.g. lowlands, uplands and coast). These rules also enable estimates to be made on the abundant species in the habitats.

Once all the rules were established, the classification process could begin on each of the segmentation levels established previously (*super-level,* level 1 and *sub-level*).

An amalgamation process is required to ensure that the Phase 1 classes are consistent with the classes obtained using the object oriented classification method. While there was direct correspondence for some habitats such as open waters, broadleavened woodlands, bracken and urban areas, for example, certain other classes had to be re-constituted using a set of fusions in order to reconstruct the initial nomenclature. This fusion is also carried out by establishing rules (implemented in C++) based on the composition of each habitat from Phase 1 (proportion and distribution of the sub-habitats, the abundance of species, etc.).

Channel	Key habitats
1. Green (summer)	Broadleaved woodland, lowland wet heath, uplands bogs and dry heath (*Calluna*-dominated), sand
2. Red (summer)	Non-vegetation, ploughed fields, felled coniferous forest, marshy grasslands (*Molinia*-dominated) in lowlands and uplands, gorse (coastal), dune slacks
3. NIR (summer)	Water, bracken, hedgerows, improved grassland, gorse (coastal)
4. SWIR (summer)	Bracken, coniferous forest, improved grasslands, lowland mires and fens, upland unimproved grasslands (*Festuca*-dominated)
5. Green (spring)	Broadleaved woodland, hedgerows, lowland marshy grasslands (*Juncus*-dominated), rock, gorse (coastal), saltmarsh
6. Red (spring)	Water, lowland mires and fens, lowland scrub, upland marshy grasslands (*Juncus*-dominated), upland heaths (*Calluna*-dominated), grey dunes
7. NIR (spring)	Water, improved grasslands, upland unimproved grasslands (*Festuca*-dominated), coastal grasslands, rock, gorse (coastal)
8. SWIR (spring)	Water, coniferous forests, lowland/upland marshy grasslands (*Molinia*-dominated), lowland unimproved grasslands. Upland unimproved grasslands (*Nardus/Festuca*-dominated), coastal scrub
9. Vegetation clusters	Open water, gorse
10. Shade fraction (spring)	Gorse and other scrub
11. PV fraction (spring)	Bare ground, lowland/upland semi-improved grasslands, grey dunes, yellow dunes
12. NPV fraction (spring)	Lowland wet heath, upland bogs and dry heaths (*Calluna*-dominated), coastal scrub, dune slacks
13. Shade fraction (summer)	Rock features, coniferous forest
14. PV fraction (summer)	Bracken, lowland/upland semi-improved grasslands
15. NPV fraction (summer)	Bare ground
16. Elevation	Bracken, coniferous forest, coastal habitats
17. Slope	Bracken, coniferous forest, lowland/upland *Molinia*-dominated marshy grasslands, lowland mires and fens and wet heath, bog (*Eriophorum*-dominated and unmodified), cliffs

Index	Formula	Key habitats
Standard indices		
18. NDVI (spring)	$\frac{\rho_n - \rho_r}{\rho_n + \rho_r}$	Lowland scrub, upland marshy grasslands (*Juncus*-dominated), improved grasslands (uplands)
19. NDVI (summer)[1]	$\frac{\rho_n - \rho_r}{\rho_n + \rho_r}$	Lowland flushes and marshy grasslands, gorse and unimproved/improved grasslands. Broad-leaved woodland and larch plantation. Acid flushes, non-vegtation, unmodified bogs (*Eriophorum*-dominated), dry heath (*Calluna*-dominated)
20. NDVI (summer)[2]	$\frac{\rho_n - \rho_r}{\rho_n + \rho_r}$	Lowland mires and improved grassland, broadleaved woodland, felled coniferous forest, lowland mires and fens, saltmarsh
Band ratios		
21. Green:SWIR (summer)	ρ_g/ρ_s	Broadleaved woodland, rock, yellow dunes
22. NIR:Red (summer)	ρ_n/ρ_r	Upland *Juncus* and *Nardus*-dominated grasslands
23. NIR:Green (summer)	ρ_n/ρ_g	Rock features
24. Red:SWIR (summer)	ρ_r/ρ_s	Rock features
Band differences and products		
25. NIR-SWIR (spring)	$\rho_n - \rho_s$	Lowland unimproved grasslands
26. NIR-SWIR (summer)	$\rho_n - \rho_s$	Upland unimproved grasslands (*Nardus* and *Festuca*-dominated)
27. SWIR-NIR (summer)	$\rho_s - \rho_n$	Wet bog with *Eriophorum* spp
28. SWIR-NIR (spring)[3]	$\rho_s - \rho_n$	Sphagnum bog, coniferous forest
29. SWIR-Green (spring)[3]	$\rho_s - \rho_g$	Coniferous forest
30. NIR x Green	$\rho_n\rho_g$	Gorse and other isolated or contrasting patches of vegetation, hedgerows
31. NPV-PV fraction (spring)	$NPV_{spring} - PV_{spring}$	Hedgerows
32. Normalised seasonal red difference	$\frac{\rho_{r\,spring} - \rho_{r\,summer}}{\rho_{r\,spring} + \rho_{r\,summer}}$	Lowland/upland marshy grasslands (*Juncus*-dominated), dry heath (*Vaccinium*-dominated), unmodified bogs (*Eriophorum vaginatum*-dominated)
Relative difference to neighbours		
33. NIR reflectance (summer)[4,5]	$\rho'_n - \rho_n$	Gorse and other isolated contrasting patches of vegetation, hedgerows
34. Green reflectance (summer)[4,5]	$\rho'_g - \rho_g$	Hedgerows
35. SWIR (spring)[5]	$\rho'_s - \rho_s$	*Juncus*-dominated upland marshy grasslands
Seasonal difference images		
36. Green difference	$\rho_{g,spring} - \rho_{g,summer}$	Flushes (*Juncus*-dominated)
37. Red difference	$\rho_{r,spring} - \rho_{r,summer}$	Upland unimproved grasslands (*Festuca*-dominated), gorse scrub, felled woodland
38. NIR difference	$\rho_{n,summer} - \rho_{n,spring}$	Grasslands (*Festuca*-dominated) with bracken, hedgerows
39. SWIR difference	$\rho_{s,summer} - \rho_{s,spring}$	Lowland mires and fens, felled woodlands
40. NDVI difference	$NDVI_{summer} - NDVI_{spring}$	Grasslands (*Nardus* and *Festuca*-dominated), unimproved grasslands, felled woodland
41. PV fraction difference	$PV_{summer} - PV_{spring}$	Lowland/upland grasslands (*Molinea*-dominated), bracken, mature *Calluna*
42. NPV fraction difference	$NPV_{summer} - NPV_{spring}$	Larch plantations
43. Green difference: SWIR difference	$\frac{\rho_{g,spring} - \rho_{g,summer}}{\rho_{s,summer} - \rho_{s,spring}}$	Hedgerows Grasslands (*Juncus* or *Nardus*-dominated), gorse
44. NIR (spring) & green (summer)	$\rho_{n,summer} + \rho_{g,summer}$	Upland improved grasslands
45. NIR (spring) & SWIR (summer)	$\rho_{n,spring} - \rho_{s,summer}$	Upland unimproved grasslands (*Nardus*-dominated)
Other indices		
46. Based on spring imagery	[illegible]	Hedgerows, Larch plantations, broadleaved woodlands and dense scrub
47. Based on summer imagery	[illegible]	Lowland mires and fens and *Festuca ovina* grasslands (steep slopes, lowlands and uplands). Unmodified bogs (*Eriophorum*-dominated), dense scrub and broadleaved woodland. Dry heath (*Vaccinium*-dominated)
48. Based on spring imagery	[illegible]	Lowland semi-improved grasslands
49. Based on summer imagery	[illegible]	Lowland semi-improved grasslands
50. Based on summer imagery	[illegible]	*Vaccinium*-dominated dry heath
51. Based on spring imagery	$\rho_n\rho_g$	Hedgerows, broadleaved woodland, gorse. Lowland/upland marshy grasslands (*Juncus*-dominated), upland dry heath (*Calluna*-dominated), upland unimproved grasslands (*Festuca*-dominated)
52. Heath detection	$\rho_s - \rho_r\rho_s$	Lowland heath and scrub
53. Gorse detection	$\frac{\rho_{g,spring} - \rho_{g,summer}}{\rho_{s,summer} - \rho_{s,spring}}$	Gorse

[1] Indices based primarily on SPOT-5 HRG summer (March) imagery.
[2] IRS or SPOT summer (July) imagery.
[3] ASTER data only.
[4] SPOT High Resolution Geometric (HRG).
[5] ρ' represents reflectance of the neighbouring object.

Figure 16: Bands and indices used to establish the classification rules

The methodology presented above established a set of products, namely:

A map of sub-habitats at 1:25000 (initial spatial resolution of 5 metres)

This is a map of Wales divided into 105 sub-habitats, from coastal areas to lowland and upland regions. In comparison to the original classification from Phase 1, the classification of sub-habitats provides a more detailed segmentation of the communities present. In particular, it enables a relative and approximate measurement of the proportions of dominant species or the genera associated with each object to be produced, providing a greater level of detail.

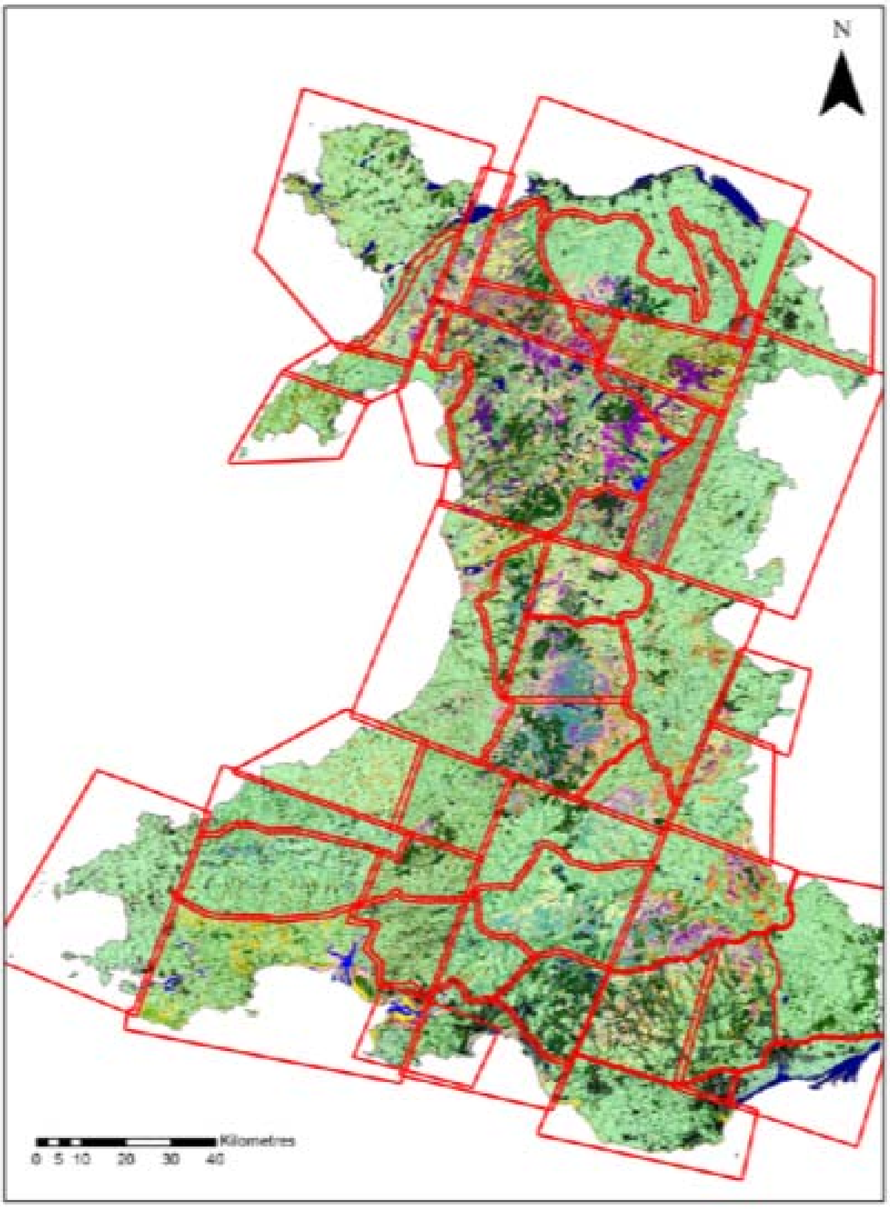


Figure 17: Map of the 105 sub-habitats in Wales

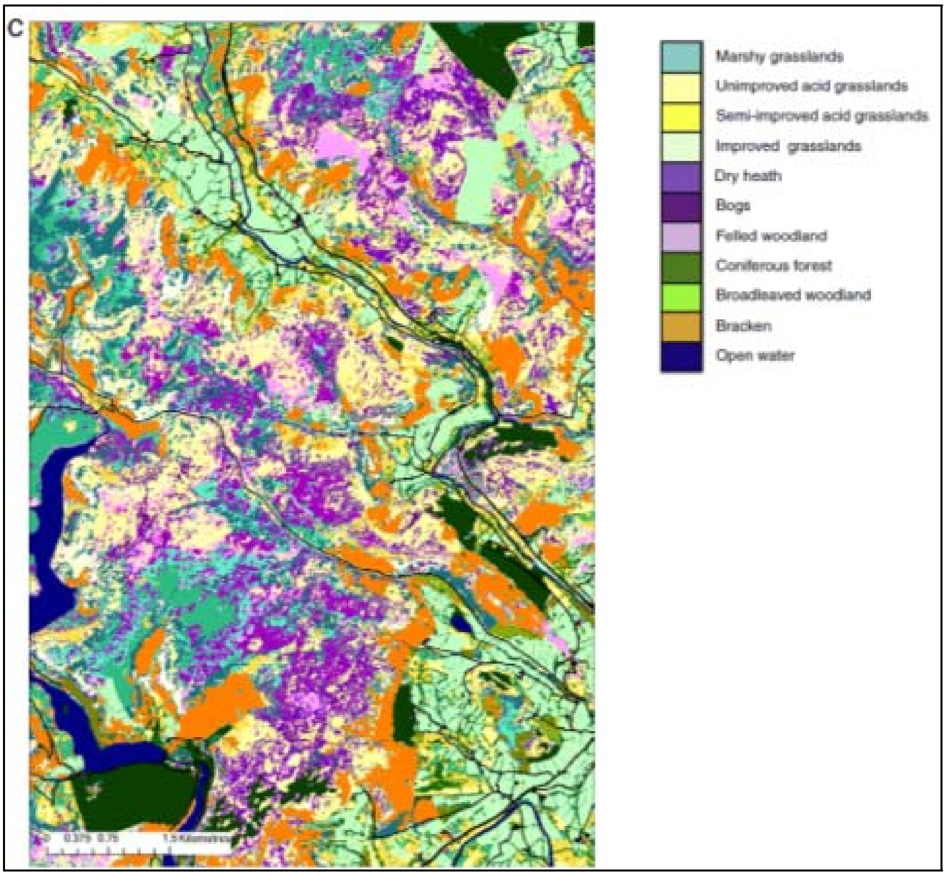


Figure 18: Map of the sub-habitats in the Cambrian Mountains region

The Phase 1 map revised to 1:25000

This map is actually still in the process of being produced and will be the subject of future reports. It involves generating a revised Phase 1 map using the sub-habitats map. This map is less detailed than the sub-habitats map. However, examples are not available. The translation of habitats at levels lower than the habitats in Phase 1 involves certain losses in terms of spatial and thematic accuracy. However, the maps obtained enable the general landscape of the country to be visualised and show a high level of detail for each habitat. The periodicity of the updates for this map have not yet been decided, but updates every three years are envisaged, following the development of technologies from the European GMES programme, amongst others.

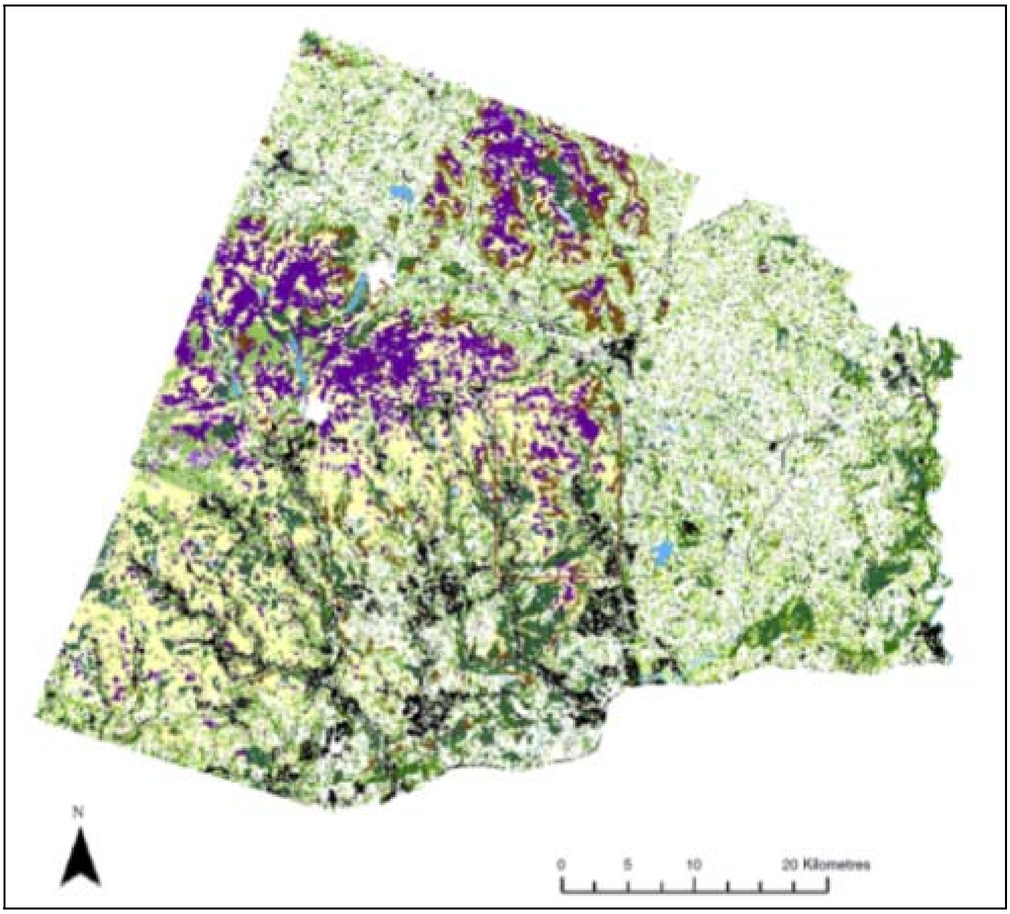


Figure 19: Example of the revised map for the south-east of Wales

Woodland and scrub		**Heathland**		**Open water**		**Rock exposure and waste**	
A1.1.1	Semi-natural broadleaved woodland	D1.1	Dry acid heath	G1	Standing water	I1.3	Limestone pavement
A1.1.2	Planted broadleaved woodland	D1.2	Dry basic heath	G2	Running water	I1.4	Other rock exposure
A1.2.1	Semi-natural coniferous woodland	D1.3	Scattered dry heath	**Coastland**		I.1.4.1	Acid/neutral rock
A1.2.2	Planted coniferous woodland	D2	Wet heath	H1.1	Intertidal mud/sand	I1.4.2	Basic rock
A1.3.1	Semi-natural mixed woodland	D3	Lichen/bryophyte heath	H1.2	Intertidal cobbles/shingle	I1.5	Cave
A1.3.2	Planted mixed woodland	D4	Dry heath/acid grassland mosaic	H1.3	Intertidal rocks/boulders	I2.1	Quarry
A2.1	Dense scrub	D5	Wet heath/acid grassland mosaic	H2.4	Scattered salt marsh plants	I2.2	Spoil
A2.2	Scattered scrub	D6	Basic dry heath/calcareous grassland mosaic	H2.6	Salt marsh	I2.3	Mine
A3.1	Scattered broadleaved trees	**Mire**		H.3.1	Mud/sand above mhw	I.2.4	Refuse-tip
A3.2	Scattered coniferous trees	E1.6.1	Blanket bog	H3.2	Shingle/gravel above mhw	**Miscellaneous**	
A3.3	Scattered mixed trees	E1.6.2	Raised bog	H4	Rocks/boulders above mhw	J1.1	Arable
A4.1	Felled broadleaved woodland	E1.7	Wet modified bog	H6.4	Dune slack	J1.2	Amenity grassland
A4.2	Felled coniferous woodland	E1.8	Dry modified bog	H6.5	Dune grassland	J1.3	Ephemeral/short perennial
A4.3	Felled mixed woodland	E2	Flush and spring	H6.6	Dune heath	J1.4	Introduced scrub
Grassland and marsh		E2.1	Acid/neutral flush	H.6.7	Dune scrub	J.1.5	Gardens
B1.1	Unimproved acid grassland	E2.2	Basic flush	H6.8	Open dune	J3.4	Caravan site
B1.2	Semi-improved acid grassland	E2.3	Bryophyte-dominated spring	H8.1	Hard cliff	J3.5	Sea-wall
B2.1	Unimproved neutral grassland	E3	Fen	H8.2	Soft cliff	J3.6	Buildings
B2.2	Semi-improved neutral grassland	E3.1	Valley mire	H8.4	Coastal grassland	J3.7	Track
B3.1	Unimproved calcareous grassland	E3.1.1	Modified valley mire	H8.5	Coastal heath	J4	Bare ground
B3.2	Semi-improved calcareous grassland	E3.2	Basin mire	H8.6	Coastal heath/coastal grassland mosaic	NA	Not accessed land
B4	Improved grassland	E3.2.1	Modified basin mire	**Rock exposure and waste**			
B5	Marshy grassland	E3.3	Flood-plain mire	I1	Natural rock exposure		
B5.1	Marshy grassland Juncus-dominated	E3.3.1	Modified flood plain mire	I1.1	Inland cliff		
B5.2	Marshy grassland Molinia-dominated	E4	Bare peat	I1.1.1	Acid/neutral inland cliff		
Tall herb and fern		F1	Swamp	I1.1.2	Basic inland cliff		
C1.1	Bracken	F1.1	Scattered swamp	I1.2	Scree		
C1.2	Scattered bracken	F2.2	Inundation vegetation	I1.2.1	Acid/neutral scree		
C2	Upland species rich ledges			I1.2.2	Basic scree		
C3.1	Tall ruderal herb						
C3.2	Non-ruderal herb and fern						

Figure 20: Habitats from the revised Phase 1 map

2.5.4.3. Accuracy of the map

The methodology used has also enabled significant levels of accuracy to be achieved. A general accuracy of over 80% was attained for the revised Phase 1 map. The accuracy oscillates between 70-90% for the majority of classes. The validation work is carried out based on the Phase 2 map and the associated areas covered (random samples). To re-iterate, this map is not global, but only local. In addition, the precision varies depending on the project.

Depending on the project covered by the Phase 2 map, several classes achieved over 80% accuracy, such as, for example, the classes of broadleavened and coniferous woodlands, certain improved and marshy grasslands, water and bracken (essentially homogenous and continuous classes of vegetation). The lowest levels of classifications were attained for the classes of scrub and semi-improved grasslands (for example, 39% and 34% respectively on certain projects). These low percentages are mainly explained by the fact that these regions were the least observed. In addition, it is necessary to clarify that the accuracy of the classification varies depending on the project. This variability is principally due to the variations in the environmental conditions within and between the biogeographical regions (e.g. shadows due to steep slopes in mountainous areas, low solar angle, the presence of clouds obscuring the land, etc.).

	Woodland				Grassland and marsh														
	A1.1 broadleaf (semi-natural)	A1.2 coniferous plantation	A2 scrub	A4 felled	B1.1 unimproved (acid)	B1.2 semi-improved	B2.1 neutral	B4 improved	Marshy grassland		B6 poor semi-improved	C1.1 bracken	E2 flush & spring	G1 water	I1 rock and waste land	J1.1 arable	Hedges (with trees)*	J3.6 urban	J4 bare ground
									B5.1 Molinia	B5.2 Juncus									
Correct (area, m²)	109 090	2639	63	971	62 287	79 792	7573	81 384	7075	7247	33	11 757	0	2248	736	3133	31 550	2199	2077
Incorrect (area, m²)	18 998	323	98	291	19 600	28 767	4533	11 012	2271	425	63	2299	13	497	200	0	8543	470	0
Correct (%)	85.2	89.1	39.1	76.9	76.1	73.5	62.6	88.1	75.7	94.5	34.1	83.6	0.0	81.9	78.6	100.0	78.7	82.4	100.0
Overall accuracy (%)	80.71																		

* No code because not mapped as a habitat in the original Phase 1 survey.

Figure 21: Accuracy of the revised Phase 1 map on one of the projects covered by the Phase 2 map (Torfaen, southern Wales)

2.6. Resources used

The CCW appointed a Project Coordinator internally, an expert in topography and remote sensing. The Project Coordinator consulted the personnel of the CCW throughout the project to find out their needs and requirements, which represented about two to three weeks' work per year for the staff. In addition, the BNSC and the University of Aberystwyth provided their assistance free of charge.

From a financial point of view, the start of the project was facilitated by the BNSC contributing up to 50% of the finance to fund the feasibility study and the initial tests. Throughout the project, the Coordinator preferred to buy archive satellite images due to the fact that they are less expensive and it is possible to check their quality before purchase. Furthermore, the CCW's financial year ends in March/April. As the most useful images are taken during this period, it is quite difficult to commission images at this time from an administrative point of view. Buying archive images enables this type of problem to be overcome.

With regard to costs, the feasibility study cost £30,000. Half of this amount was covered by the CCW and the other half by the United Kingdom Space Agency (UKSA).

Furthermore, the mapping of the four test areas phase cost £45,000 and updating the map of natural habitats in Wales cost £200,000 for the whole country.

It should be noted that these figures are only rough estimates. The costs in detail are to be evaluated on a case-by-case basis.

2.7. Future changes

The CCW personnel are just beginning to work with the new habitat map and to identify ways in which they can improve their old ways of working.

With the issues of biodiversity and nature conservation being more predominant politically, the decision-makers have arrived at the conclusion that the best way to manage them is to get all the public services responsible for the countryside and the natural heritage to cooperate in order to ensure that they all work towards achieving the same objectives. This is only possible if good quality information on species and habitats is available to everyone. Consequently, the Welsh Government recently launched a public consultation on a potential *Natural Environment Framework*[6] for Wales, which could lead to increased cooperation between the public agencies in terms of sharing the same data sets.

2.8. Conclusions and lessons learned

Developing a methodology for updating habitat maps using satellite imagery enabled the CCW to learn a number of lessons. Here are some of those conclusions:

1. The crucial support of the BNSC in the project.

For such ambitious projects where success is not guaranteed, managing expectations and risks is a significant challenge. During the initial stages, that was made possible with the support of the BNSC, which provided not only expertise, quality control and funding, but also contracted the service providers on behalf of the CCW.

2. The importance of buying archive images in order to manage the budgets effectively.

From a financial point of view, buying archive images enabled the project budgets to be controlled. Buying archive images also enabled the quality of the images to be checked before purchase. Furthermore, at the end of the year, underspends from the other CCW departments were used to buy additional data.

3. The importance of the service providers *Environment Systems* and the University of Aberystwyth (independent experts in the field of geomatic sciences) to the success of the project.

The project was divided into three distinct stages (feasibility study, tests and deployment), each with its own tender process, thus ensuring that the most suitable and competent service provider was chosen to complete the habitat map updating for the whole of Wales. The terms of all the contracts stipulated that payment would only be made once the results were operational and that they were in accordance with the CCW's specifications. While the CCW retains the rights to the imagery, *Environmental Systems* and the University of Aberystwyth share the intellectual property rights to the method developed with the CCW and are authorised to use the method within the university and for research, as well as for other commercial purposes with the CCW's permission.

[6] http://wales.gov.uk/consultation/desh/2010/100909livingwalescons/100908alivingwalesconsultation?lang=en

4. Involve regional and local stakeholders in the project development.

With regard to the internal procedures, the decision to involve the staff in the regional offices in the quality control phase of the map updates, as well as the later stages, helped everyone to understand the reasons for choosing this method, and its impact on future working methods, which contributed to its successful management in the future.

In addition, the specifications of the new map were formulated to meet the internal needs and obligations of the CCW and the regional offices with a view to possible developments in the longer-term for data sharing with different organisations, but without taking the specific needs of external stakeholders, such as local authorities, specifically into account.

5. Satellite information is of use to Wales for updating the habitat map.

Producing the new map using satellite data represented a minimum financial investment compared to the previous version. Furthermore, it is key that the updates are quick and cost-effective. If we exclude the research phase (developing the methodology used to determine the sequence of images to analyse and how to interpret these images), the new approach represented less than a tenth of the cost of the previous map, which was produced using data from a field study involving three teams of ten field researchers over 15 years. This represents a drastic decrease in terms of the time and resources used. However, the previous habitat mapping in Phase 1 was a necessary step towards producing the habitat map using satellite imagery.

From the point of view of the methodology used, this experience in Wales is one of the first applications of an object oriented classification method at a national level based on detailed rules of habitats (rather than to wider classes of land use). The rules were developed on the basis of ecologists' and remote sensing experts' knowledge and expertise using eCognition software. The methodology applied in this project enabled a higher level of detail on the maps to be obtained. This was particularly due to:

- the use of SPOT-5 HRG data and vector data from the LPIS during the initial segmentation of the landscape into objects;
- the consistency between the SPOT, ASTER and IRS data, despite the different dates they were acquired, due to geometric, radiometric, atmospheric and topographical corrections being rigorously applied. However, this multi-captor and multi-date approach made the pre-processing phase considerably longer;
- the application of a set of logical rules and operators for classifying the habitats. This set enabled the knowledge of ecologists on the characteristics of the different communities and the knowledge of remote sensing experts to be used. Furthermore, these rules can be adjusted over time, enabling new criteria to be integrated and old criteria to be updated. It remains to be seen whether the method used in this example can be transposed to the regions of Nord-Pas de Calais and Kent. For example, in the Nord-Pas de Calais, the landscape is more fragmented than in Wales which has large and homogenous expanses of landscape;
- in addition, one of the advantages of the methodology is the use of a multi-temporal approach to take into account the seasonal variabilities of plant communities for classifying habitats. It is by using this multi-temporal aspect that the remote sensing could make a difference in comparison to the more classic CAPI methods which can only exploit one date.

With the existing spatial information, namely the old Phase 1 habitat maps and the updated version, the CCW now has a habitat map which is more detailed on a spatial level than the previous one, and which supplements the field work, for which inaccuracies still remain. The personnel at the CCW can therefore, for example, identify the possible corridors between protected sites (or their insufficient numbers) which enable species to migrate safely, to protect them (from the construction of a road, for example) or to move them.

The new map presents a sufficient level of accuracy and contains an adequate number of layers, which will eventually enable several agencies (the CCW, the Forestry Commission, the Environment Agency, the Welsh National Assembly, and local authorities, etc.) to collaborate using the same base data.

For example, the valleys in the County of Glamorgan in the south of Wales have benefitted from the updated habitat map. The local authorities have used the information derived from the map to identify possible Sites of Specific Scientific Interest (SSSIs). It is estimated that 65% of the land that would have been the subject of a study were excluded from the list of habitats of interest (arable land, grasslands, etc.). A 3-colour traffic light system has been created for maps (high/medium/low probability) for potentially rich grasslands in order to target the field work accordingly, which has resulted in a decrease in the overall cost of the project and a large increase in the number of sites found.

6. Adaptation is still required in order to make the most of the new products.

To go from a habitat map based on field surveys to a vector map derived from satellite imagery is a big change for the CCW personnel to adapt to. The limits of the old map were well known (geo-referencing inaccuracies, lack of detail, etc.) and the ways of working were adapted around them to compensate. The new map also has its own set of uncertainties, inherent in all new ways of working: How can the accuracy of a vector map be checked? What are the accuracy percentage rates of the map? Can the map be reproduced? These questions will undoubtedly be answered in the future through the map being used as a part of normal professional practice.

Grouping together the different sets of spatial information data in a GIS using geoinformatics is still seen as a source of difficulty. This should be resolved as the functionality of the software develops.

3. Good practice in the German Federal State of Brandenburg: "Mapping protected heaths in Brandenburg – the National Office from the Environment, Health and the Protection of Consumers (LUGV)"

The German Federal State of Brandenburg covers 29,500 km². Under Natura 2000, 27 *Special Protection Areas* and 620 *Special Areas of Conservation* cover 36% of the territory. Today, the biotopes of heaths cover 120 km².

3.1. Organisation: structure, mission and objectives

The National Office for the Environment, Health and Consumer Protection (LUGV in its German abbreviation) comes under the Ministry for the Environment, Health and Consumer Protection of the German Federal State of Brandenburg. With regard to the environment, the LUGV's remit is to:

- provide expertise (including technical expertise) to the relevant ministries (for drafting different policies) on conservation issues and protection measures for local authorities and their agencies;
- manage the national parks in the region, the nature reserves and the biosphere reserves;
- monitor and produce reports on the status and development of Natura 2000 sites and species;
- manage the Natura 2000 sites and species;
- identify and protect conservation areas for nature and the landscape;
- contribute to informing and communicating with the general public on nature conservation.

To achieve these aims, the LUGV needs comprehensive cartographic information on habitats, species and their development. The Department in charge of the Natura 2000 sites and the Protection of Species and Habitats is responsible for acquiring, collecting, formatting and analysing the data obtained from field work and remote sensing (both aerial and spatial).

3.2. Challenges

The State of Brandenburghas large areas on its territory which are or were former military training grounds. Even though the majority of them are demilitarised, the soil in these areas remains contaminated by munitions, making physical access to the land for field work dangerous. However, the habitats in ten of these areas are likely to contain European dry heaths (Natura 2000 habitat type 4030, presented, in the majority of cases, as a mosaic with the habitat types 2310, 2330 and 6120), and constitute the majority of the heaths in the State of Brandenburg.

The LUGV has aerial photographs dating from 1992, covering the whole territory, as well as continuous terrain data. As aerial imagery does not produce enough detail to be able to identify habitats and species, and because field work cannot be carried out on the former military zones, the habitat maps produced by the LUGV contained ten significant areas which were devoid of information.

However, the entry into force of the Directive on Habitats prompted the LUGV to find alternative methods for mapping these relatively small areas (in comparison to the State as a whole), with a sufficient level of information and at a reasonable cost (proportionate and in-line with public expenditure).

3.3. Interaction and dissemination of information

The importance of the heath habitats and their inaccessibility for field work and analysis was the subject of a research thesis at the Berlin Technical University at the beginning of 2000. This research project looked at the potential of using Very High Resolution satellite images for mapping heath habitats. It was supervised by a remote sensing expert at the LUGV who recognised the potential of the methodology to meet the LUGV's mapping needs.

Between 2005 and 2009, the LUGV progressively obtained QuickBird satellite images covering the ten expanses of heaths and employed the services of the local company *Luftbild Umwelt Planung GmbH* to apply the method developed for identifying heaths on the Very High Resolution images acquired.

The map and detailed information on the heath habitats, obtained using satellite imagery, were, in the main, integrated into the LUGV's internal GIS. However, information concerning the most recently mapped regions is currently still being integrated.

The initial acquisition of information on the heath habitats was financed by the LUGV. However, since this first acquisition, and due to overlaps with local research projects on nature conservation, for one area of the heaths it was possible to update the information obtained using satellite imagery bought in 2005 with analyses of more recent satellite images made available to the LUGV.

3.3.1. Producing the information on the heath habitats

In order to map the inaccessible regions of the heathlands, the LUGV bought raw satellite images recommended by the service provider, before making them available to the service provider for pre-processing, interpretation and analysis. The later then supplied the LUGV with the mapping data combined with detailed information on the status, extent and location of the heath habitats.

Within the LUGV, the Department for Natura 2000 and the Protection of Habitats and Species was responsible for controlling the quality of the data produced, before integrating the databases into the LUGV's geographical information system. Due to the complexity of integrating into a single GIS data on habitats and species from different sources (field visits, aerial photographs, satellite images, etc.) and presented in various forms, the LUGV was supported by the University of Applied Sciences in Eberswalde.

While the majority of the complex detailed information on habitats and species is only available on the internal GIS, the LUGV has also made some selected information available on its website for public consultation purposes.

For example, this includes the most important types of information which planning offices traditionally require in order to compile impact studies for authorising planning applications.

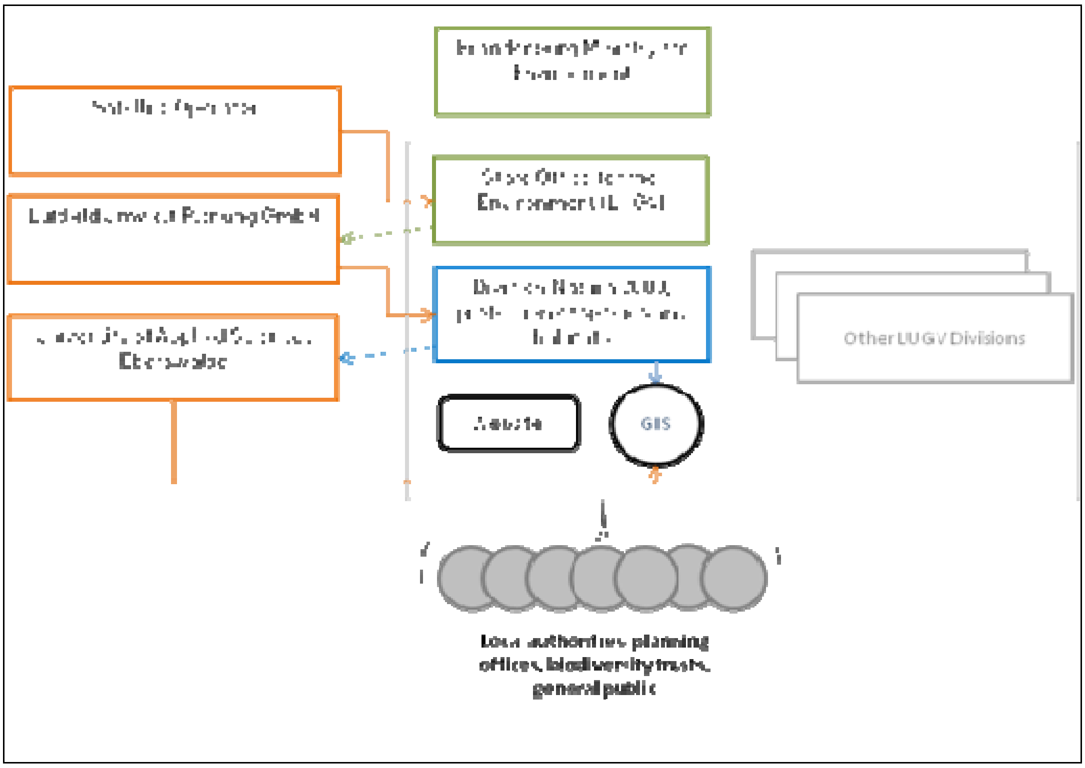


Figure 22: Information production

3.3.2. Using the information

The information on the heathlands, derived from satellite imagery, is used both internally and externally. Within the LUGV, the Department for Natura 2000 and the Protection of Habitats and Species participates in producing the information and integrating it into the GIS. It is also one of the first to use the information for: (a) monitoring the status and development of the protected habitats and meeting the reporting obligations for Natura 2000 sites at a regional, national and European level; (b) providing expertise and input into developing the policies of the relevant LUGV departments, and also possibly of the Ministry for the Environment; and (c) monitoring and assessing the conservation measures implemented by the municipal offices responsible for managing the protected areas.

In addition, within the LUGV, the departments responsible for managing the national parks, the nature reserves and the biosphere reserves may, if the areas which they manage contain heaths, consult the information in order to inform their conservation measures and to evaluate the impact of public projects.

In the State of Brandenburg, management companies and biodiversity organisations, both very active in nature conservation, have taken over the management of many of the demilitarised zones containing heaths. Along with landowners (public and private), local authorities responsible for managing protected areas, planning offices and different stakeholders, these management companies and associations can apply to have access to the useful information held by the Natura 2000 Department (if the information available on-line is not sufficient), in order to establish or revise management plans, make the most appropriate choice in terms of conservation measures or to undertake impact studies.

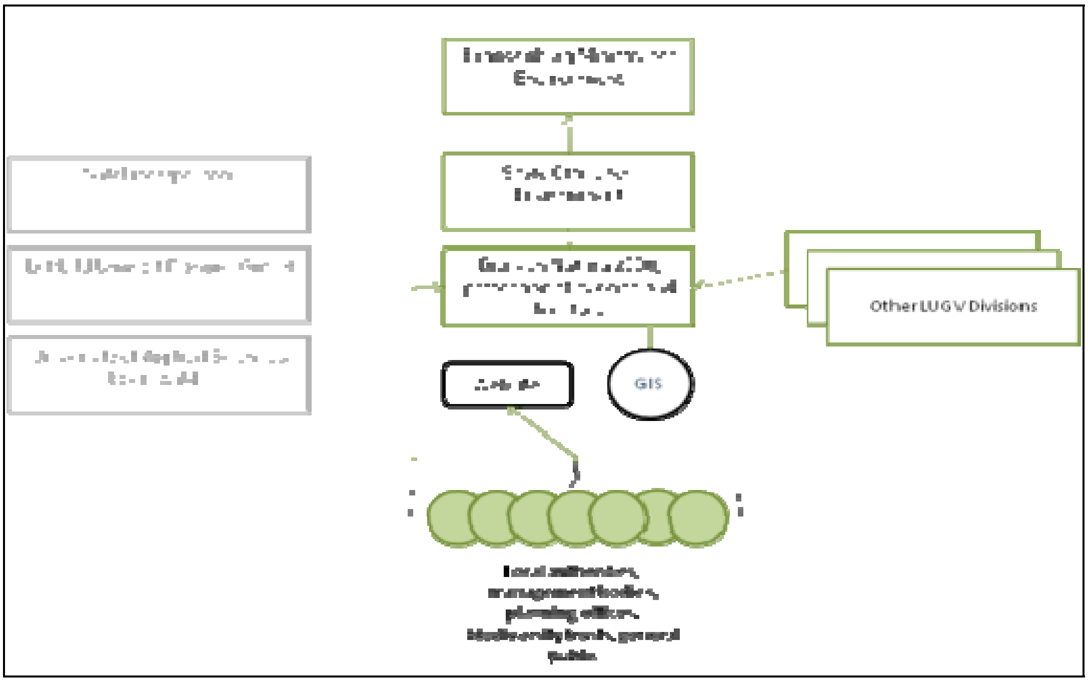


Figure 23: Information use

3.4. Methodology for interpreting the information obtained from remote sensing[7]

3.4.1. The approach used for extracting information

In connection with the Federal State of Brandenburg's need for information on the 120 km^2 of heathlands contaminated by former arms and munitions and now a Natura 2000 site, the R&D SARA'04 project(*Satellite-based Regional monitoring for environment Applications*, 2003-2006) enables the development of analysis methods based on Very High Resolution multi-spectral satellite data. While the first stages of development were connected with monitoring and assessing the Natura 2000 habitat types 4030 and 2310, the method has now been extended to include other habitat types. The first habitats corresponded to the dry heaths type (4030) and dry sand heaths (2310). While the latter habitat is characteristic of the German-Baltic region, the first habitat corresponds to post number 312 of the ARCH nomenclature or 31.2 of the CORINE Biotopes.

The methodology developed focused on semi-automatic pixel-based classification methods (supervised classification) coupled with a set of information constituting a "knowledge base". In particular, this consists of old maps of biotopes or land use, and ecological knowledge applied to remote sensing data such as the NDVI vegetation index, etc.

This approach was used instead of object oriented classification methods as the transferability and repeatability for these methods are more complex. Pixel-based approaches also have the advantage of maintaining the high detail of spectral information of the images.

[7] Frick, A., Weyer, G., Kenneweg, H. & Kleinschmit, B., 2005. A knowledge-based approach to vegetation Monitoring with QuickBird imagery. ISPRS Workshop 2005 – High Resolution Earth Imaging for Geospatial Information, May 17-20, 2005, Hannover.

In developing these methods for analysing VHR satellite images, the main objectives sought are: transferability, repeatability and impartiality.

3.4.2. Data

The observation made by the service provider is that Very High Resolution satellite images have many advantages including offering comparable resolutions to aerial photographs, less expensive data and faster acquisitions. In addition, they are in a digital format which means that they can be integrated directly into a geographical information system.

The approach therefore explores the potential of VHR images for monitoring habitats and biotopes. During the first stages of the methodology development, VHR QuickBird satellite images were acquired (for the period August 2003 – September 2004). The QuickBird images were composed of four spectral bands covering a range of 430-918 nm at a resolution of 2.69 metres in multispectral mode and 0.67 metres in panchromatic mode. This first test phase was carried out using these images because they had the best resolution out of the images available at the time. Even today, the majority of the images purchased are QuickBird images. However, it is possible to extend the methodology to other VHR sensors (for example, WorldView-2).

Furthermore, exogenous data will be used in this approach, specifically:

- topographical data for geo-referencing the satellite images. During the test phase, ATKIS data (from 2004) was used;
- maps of biotopes and modes of land use (generally from photo-interpretation work) to populate the databases and assist the classification process;
- aerial photographs and stereoscopic couples for assessing accuracy. In particular, data from CIR-airphotos (from 1998), was used during the test phase;
- field work data for validating the classifications.

3.4.3. Data pre-processing

The usual corrections are applied to satellite images in order to make them exploitable. Firstly, each image acquired must be radiometrically calibrated and corrected. This involves turning the raw data into useable data. Then, the geometric corrections are applied. The images are now geo-referenced. Lastly, the pan-sharpened images are produced. This involves improving the spatial resolution obtained by fusing the panchromatic data with the multi-spectral data of the image. In other words, this procedure enables satellite images to be obtained in false colour at the spatial resolution of the panchromatic mode.

3.4.4. Extracting the information

The approach developed by the service provider (LUP) is based on an automatic classification method, namely a supervised classification (of the *Maximum likelihood* type). However, rather than manually digitise the training zones to establish the spectral signature for each class sought, the approach favoured extracting the pixels automatically, enabling the spectral signatures to be established. Manually delimitating the training zones on the VHR images is complicated and time-consuming. The methodology developed in this case is therefore based on an iterative and hierarchical approach (*top-down* approach). It applies to the creation of a “knowledge base” containing existing or new remote sensing and ecological information. It also enabled the experience of photo-interpreters of analysing aerial photographs to be formalised. For example, trees cast shadows on the ground. It also enabled spectral characteristics to be taken into consideration. For example, water always has a NDVI less than 0. Lastly, it integrates *a priori* knowledge in the form of geo-localised data, for example similar to the maps of biotopes (e.g. the CORINE biotope base). All of this knowledge is formalised as a set of rules, similar to the object oriented classification approach.

The first stage consists of establishing the spectral training signatures with the aim of producing the land-cover map. Next, by aggregating the pixellated classes obtained initially, the habitat/biotope maps are reconstituted. As the data used is VHR data and because each biotope can consist of several types of land use, this approach was favoured. Thus, extracting the spectral training signatures is carried out schematically as follows:

- Level 1: Firstly, the shadows are extracted from the panchromatic image on the basis of local minima and filters.

- Level 2: The information on the shadows extracted above, associated with supplementary information, such as data on the NDVI (segmented by unsupervised classification of three classes of value levels) or the presence or not of forests on biotope maps (by a request system), enables a set of rules to be established for extracting information on trees.

- Level 3: The information previously extracted coupled with the supplementary information enables base rules to be established for extracting the land-cover types sought (e.g. mosses, dry grasslands, woodlands, etc.). For example, the thresholds based on the ratios between the multi-spectral bands or on the NDVI value can be used.

- The different levels are also supplemented by the nearest neighbour rule in order to differentiate the classes from the similar spectral signatures (for example, for asphalt and water). This phase is done post-classification.

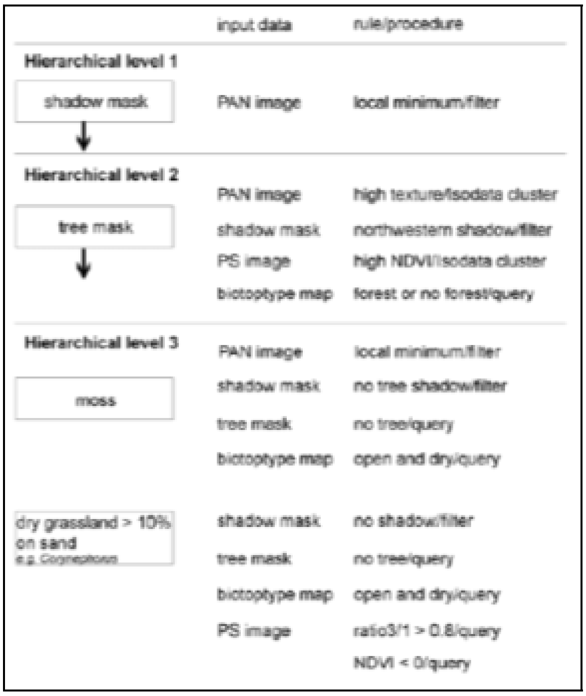


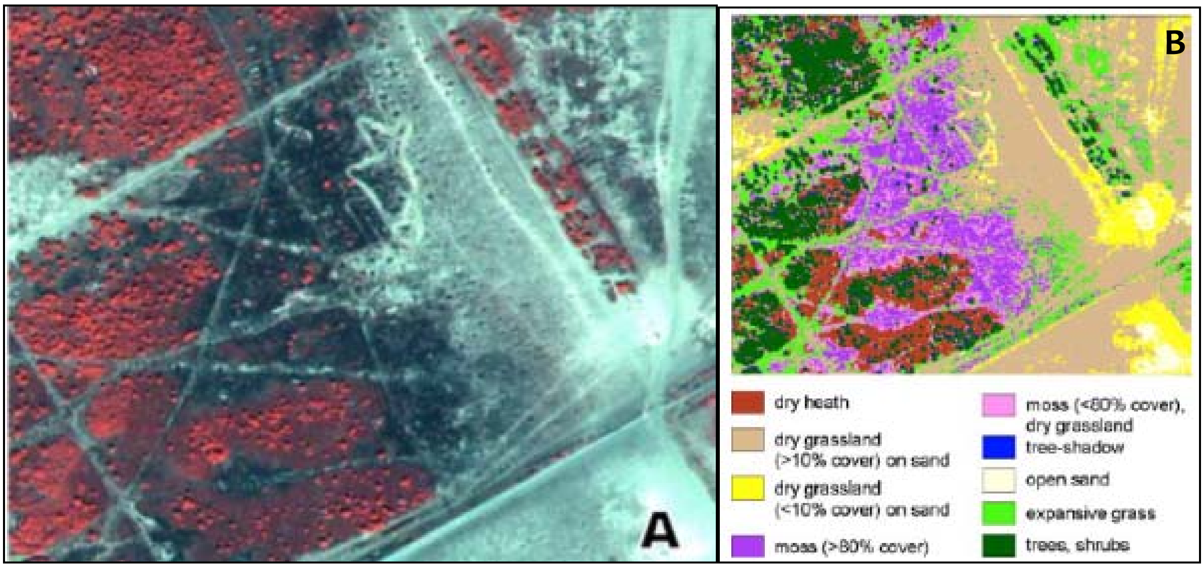
Figure 24: Example of the hierarchical levels used for extracting the spectral signatures

These different rules therefore enable the pixels representing the target class to be extracted. They are established on the Erdas remote sensing software. These pixels are used to establish a spectral signature of the associated class. This approach leads to much purer spectral signatures than by manually delimiting the training polygons.

The spectral signature types then act as training spectral signatures in the classification algorithm, thus enabling the entire image to be segmented. The first classification obtained is therefore a pixel classification of the land-cover type.

Following this first classification, a visual analysis on the GIS platform is carried out. It enables the accuracy of the polygon borders and the results of the classification to be checked. It is worth noting that the automatic extraction of spectral training signatures is not possible for all the classes. In particular, this is true for the classes not present at the time the biotope maps were produced. There are also inherent difficulties related to the date the image was taken, for example for temporarily dewatered zones. These limits can be resolved during the visual analysis phase.

Lastly, the final stage in the chain consists of the phase of reconstructing the habitat/biotope class types by aggregating the classes resulting from the pixel classification. This grouping together of classes is carried out according to the usual nomenclatures and associated compositions (e.g. the Natura 2000 habitats). It is therefore possible to reconstitute the dry heaths habitat (Natura 2000 code: 4030), for example. The associated classification and mapping method therefore enables the habitat or biotope to be evaluated.



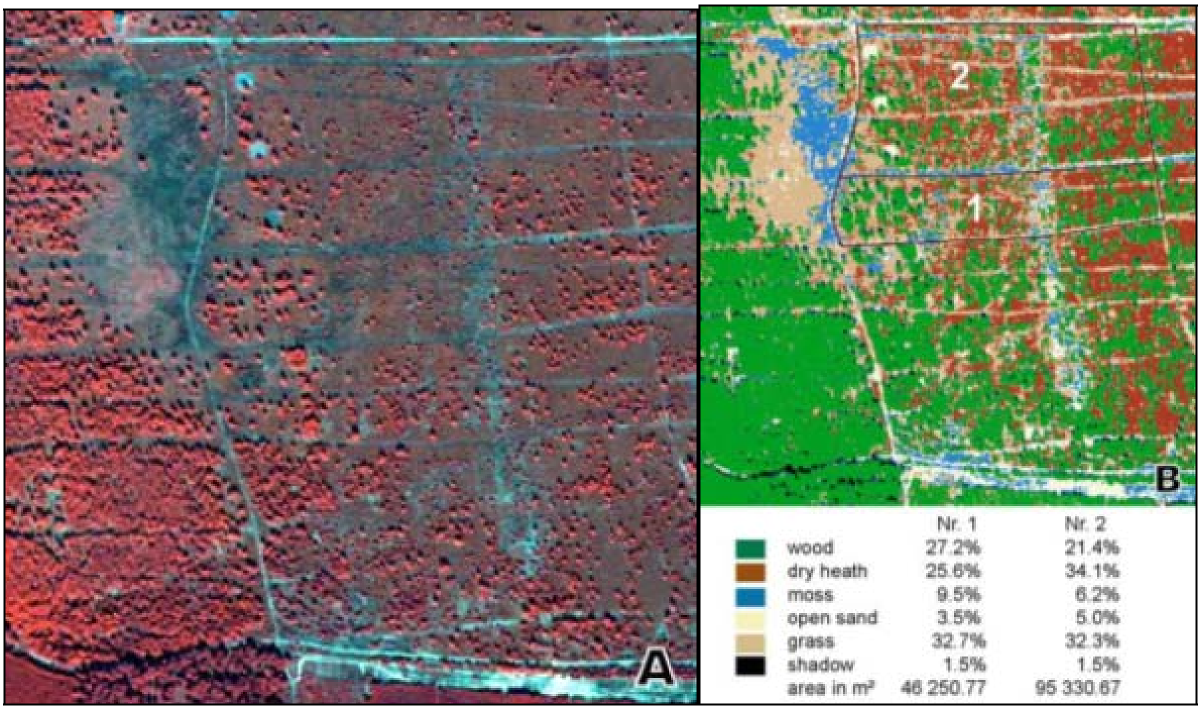


Figure 25: Examples of supervised classifications for dry heath habitats

The accuracy of each classification is established for each reconstituted habitat on the basis of validation points randomly distributed for each class (land-cover). It is based on a comparison with pan-sharpened satellite data. For example, the accuracies obtained for classes of woodlands, dry heaths/grasslands or mosses are quite significant (more than 90%). The accuracy levels are lower for the classes of wet/flooded land (70-85%). Lastly, significant difficulties remain for the agricultural classes (intensive/extensive grasslands).

3.5. Resources used to map the expanses of heathlands

While the pre-processing and interpretation of satellite images was delegated to the service provider, the principal stakeholder involved in the production, quality control and use of the data remains the Natura 2000 Department which comprises five members. Amongst these five staff members, two are dedicated entirely to the management and maintenance of data relating to the Natura 2000 sites, while the other team members are principally responsible for quality control and analysing the information on habitats and species.

3.6. Future changes

The main reason for future changes could be the availability of data other than satellite data for heathland regions. The State of Brandenburg has programmed the acquisition of aerial images of the region in 2011. As the most recent aerial images available to the LUGV date back to 1992, it is not possible for them to assess whether these future aerial images will provide sufficiently detailed information for updating the habitat map of the heathland regions. If they prove to be sufficient, the use of satellite images will then no longer be required.

Future changes on the way geographical information can be accessed and shared may also occur. There are currently a number of initiatives underway in several German States looking at the possibility of combining and sharing biodiversity data between all the stakeholders in one standardised data storage system. The LUGV is awaiting the first results from these initiatives and plans to be involved.

3.7. Conclusions and lessons learned

The LUGV was confronted with the need to acquire information on the protected habitats of heaths in areas which are inaccessible for field work, due to the high degree of danger related to the contamination of the soil by munitions. Due to the fact that the LUGV had to finance this acquisition from its own funds and in order to comply with the principle of proportionality of public expenditure for protecting a specific habitat, each envisaged solution had to be highly efficient and reasonable in terms of cost.

In addition to the inaccessibility of the areas for field work, the acquisition of aerial images for the relatively small and dispersed areas would have been less cost-effective than the solution of mapping using VHR satellite images. Its adaptation to "classical" aerial photographs and other families of sensors has not yet been considered. Finally, the LUGV is satisfied with the quality of the information resulting from this procedure and plans to update the information at regular intervals using satellite imagery for as long as this approach remains cost-effective.

The LUGV recommends choosing the satellite which is the source of the acquired imagery carefully in order to be certain that no difficulties in terms of availability and continuity for the purposes of the updates will be encountered.

The unreliability of the availability of QuickBird images was the main difficulty encountered during the process. Furthermore, this problem is likely to occur again in the future. However, the nature of the methodology and information sought requires sensors with specific characteristics which are not readily available.

Furthermore, concerning the quality of the data produced, the LUGV noted that it was very difficult to evaluate the first data acquired as there was no base for comparison. In the future, this problem shouldn't be encountered when updating the new habitat maps.

From the point of view of the methodology, the approach developed focused on one specific habitat by exploring its structure and its composition rather than creating a habitat map. These ad hoc maps were to assess and monitor the habitats, as is required by Natura 2000. An advantage of this method is that it is a hybrid method, both automated and visual, for exploiting information from Very High Resolution satellite data for monitoring biotopes and/or habitats. However, the robustness of the method during the transition from one scene to another is not certain. The differences in the angles of the views and the dates the images were acquired are problematic when it involves transposing the rules for one scene to another (e.g. plant community phenology).

4. The mapped habitats

Although the geographical locations of the different examples of good practice studied in this report are different form the interregional context of the Nord-Pas de Calais/Kent regions, there are nevertheless certain habitats in common which have been listed and mapped.

It is clear that the production of ARCH maps is confronted with difficulties when it comes to photo-interpreting certain habitats which require input from external data. One solution is to learn lessons from the projects analysed above in terms of methodology and cartographic[8] accuracy and to reflect upon them when developing solutions to the problem habitats during Mission 4.

To re-cap, the habitats which present difficulties for photo-interpretation are as follows:

- [Kent] Wet woodlands (alder and willow)
- [Kent] Vegetation on shingle beaches (highly fragmented)
- [Kent] Salt marshes – *spartina* (highly fragmented)
- [NPdC] Dunes vs. Dunes with scrub, thicket
- [NPdC] Humid dune slacks
- [NPdC] Dune slack pools
- [NPdC] Paleo-coastal dune
- [NPdC] Shingle beaches without vegetation
- [NPdC] Vegetated shingle beaches
- [NPdC] Shingles or mudflats without vegetation vs. Amphibious communities
- [NPdC] Wet heaths
- [NPdC] Dry heaths
- [NPdC] Dry calcareous steppes and grasslands
- [NPdC] Grasslands with heavy metals
- [NPdC] Dry silica grasslands
- [NPdC] Humid tall herb fringes vs. wet grasslands vs. vegetation belts bordering water
- [NPdC] Mesophile pastures
- [NPdC] Lowland hay meadows
- [NPdC] Polder forest
- [NPdC] Riparian woodlands, very wet woodlands and scrub
- [NPdC] Raised bogs
- [NPdC] Blanket bog
- [NPdC] Lower marshes, bog in transition, springs
- [NPdC] Improve grasslands
- [NPdC] Fallow land

Among the correspondences which can be established between the classes from the different projects and those from the ARCH project, it is necessary to differentiate between the correspondences which can be qualified as "perfect", where the titles of the target posts and habitats are identical (from the point of view of the CORINE Biotopes), from the correspondences called "approximate". Certain habitats were

[8]At the current stage of development in the examples of good practice (Wales and Piedmont), the final information on the questions relating to mapping accuracy are not available. An analysis and concrete proposals for solutions to the problem posts cannot therefore be given.

more finely detailed in the different examples of good practice and therefore only correspond to one single unique post in the ARCH nomenclature. The CORINE Biotopes is a hierarchical nomenclature which enables mapping levels to be more or less detailed. In contrast, it is also the case, although it occurs less frequently, that certain habitats are more detailed than the ARCH nomenclature. These are the two cases which define the notion of "approximate" correspondence.

The good practice in Piedmont

As part of the Alcotra project, the descriptions for the habitats followed the nomenclature of the CORINE Biotopes and Natura 2000. Correspondences between the mapped habitats in this example of good practice and the ARCH project were therefore easy to make.

In addition, the extraction method used in the Alcotra project meant that the habitats were more finely detailed. The satellite data was exploited to delimit the polygons only. Consequently, the habitat descriptions are more detailed.

In the end, 155 habitats were mapped during the Alcotra project. In annex 4, the table of "perfect and approximate"» correspondences between the two nomenclatures can be seen (the "perfect" correspondences are shown in green and the "approximate" correspondences in orange).

From these habitats, it is possible to establish correspondences with the habitats on the ARCH map which are difficult to photo-interpret. There is "perfect" correspondence for only one single post, namely dry heaths (CORINE code 31.2). Furthermore, 20 "approximate" correspondences were identified concerning the following five ARCH habitats: dry calcareous steppes and grasslands, raised bogs, lower marshes, bogs in transition and springs and paleo-coastal dunes.

The good practice in Wales

While the nomenclature used in the Alcotra project followed the CORINE Biotopes nomenclature, the good practice example in Wales did not use the same nomenclature. Therefore the correspondence is not direct. Therefore, a first phase to establish the correspondence with the CORINE Biotopes needs be undertaken.

In the end, 103 habitats were mapped during the project in Wales. In annex 5, the table of "perfect and approximate" correspondences between the two nomenclatures (Wales and ARCH) can be seen (the perfect correspondences are shown in green and the approximate correspondences are shown in orange).

Among the 103 habitats mapped during the project in Wales, four "perfect" correspondences with the problem habitats in the ARCH nomenclature were found and 12 "approximate" correspondences (concerning eight ARCH posts). Among the "perfect" correspondences, we find wet heaths, blanket and raised bogs and humid dune slacks, while for the "approximate" correspondences we find dry siliceous grasslands, mesophile steppes and grasslands, lower marshes, bogs in transition and springs and unvegetated shingle beaches.

The good practice in Brandenburg

In the case of the good practice in Brandenburg, the issues are different. While the end purpose of the two projects above was to produce habitat maps, in this case the aim was to depict the structure and composition of a specific habitat within the context of evaluating and monitoring Natura 2000 sites.

Therefore, using the methodology developed as part of this project, the first land-cover map enabled the habitats to be reconstituted. As of today, they have depicted habitats of the dry heaths type. However, the method used in this example could feed into a reflection on the needs expressed by users in the ARCH project for a more detailed characterisation of certain habitats.

Conclusion: transferability of the good practice

Reminder of the challenges:

It is important to remember that the situations are very different in Kent and the Nord-Pas de Calais region:

	KENT	NORD - PAS de CALAIS
Before ARCH	"centralised mapping"	"ad hoc"
The natural habitat maps in question here: Centralised regional maps		
Cartography	2 iterations 1995, 2000, 2010 (ARCH)	First time centralised (ARCH)
Classification	Detail → interregional/high level	Interregional/high level
First map	Detailed field survey (1995)	Aerial photo (CAPI) + non-exhaustive checks on the ground (ARCH) "New method"
Updating method	Previous maps + aerial photo (CAPI) Well-established method	Not yet known
Reliability	High	To be confirmed
Weak points	Well known	To be confirmed
Current implementation	Internal	Contracted out
Future implementation	Probably internal	Probably contracted out

Figure 26: Background of the provision

ARCH activity 3 involves supporting the updating of habitat maps using remote sensing rather than completely replacing all the current approaches with it.

While access to spatial and aerial remote sensing can bring new sources of information, through different spatial, temporal and spectral resolutions, these technologies will not replace detailed knowledge and analysis of the land or aerial photography.

On the other hand, it can introduce supplementary information to make detailed analysis clearer or to facilitate the analysis process (resulting in savings in terms of time and money).

The aim of Mission 1 was to identify and prioritise the areas where remote sensing could possibly be used in updating maps.

At the end of Mission 1, it was therefore decided by common agreement to focus the subsequent Activity 3 on the following components (in order of importance):

- a map of Hot Spots of Changes;
- detecting specific classes which are difficult to map with the current approach;
- including additional complementary information within certain classes of particular interest;
- automated analysis of aerial photographs for some target themes.

Generally, for all of these components, the task was to find approaches to either provide complementary information using CAPI, or to procure the information sought directly, taking into account the availability of data, its technical capacity, and compromises regarding cover and resolution, as well as the possible automations. The aim was to arrive at pragmatic, effective and operational methodologies.

The good practice in Piedmont

The good practice developed by the Piedmont region for habitat mapping, favoured a decentralised approach. In order to involve local nature conservation stakeholders (managers of parks and reserves, local administrations, etc.) so that their specific needs are targeted, it is up to each of these management bodies to establish their maps.

The general principle of the mapping methodology is based on the use of both satellite data and field work. The interpretation phase of the Very High Resolution satellite images enables the vectoral base of the polygons (geometric information) to be constituted, while the field work provides information on each of these polygons in terms of thematic content (habitats). This approach requires a lot of field work to be undertaken by each of the local management authorities, the same goes for the photo-interpretation.

The region had previously introduced mapping standards to guide each body in its mapping and to ensure consistency between the information produced by the different stakeholders. Furthermore, manuals have been produced and training has been provided.

However, if this approach is to be transferred to the Nord-Pas de Calais or Kent regions, it would need to be adapted accordingly.

In the ARCH project, the base map will be available (being produced as part of Activity 1). Future work will not be on establishing maps, but on updating them. In this context, the photo-interpretation of the data phase should guide the field visits to those areas where significant changes are observed, enabling savings in terms of money and time for the bodies responsible for them.

In addition, in the context of the Nord-Pas de Calais and Kent regions, frequent aerial photographs covering each of these regions will be taken in the future. Each body will therefore have the data required for the photo-interpretation. Buying satellite images will therefore not be necessary.

However, in the case of using satellite images, this approach would require the sharing of existing data and the sharing and centralising of future purchases of images per region. A satellite image may, in effect, serve several management bodies in the region. However, sharing the cost of purchasing images between two regions appears to be very complicated. No VHR or HR data (of most interest to this project) covering the whole of both regions at the same time exists. Data sharing would have been more feasible and relevant with Belgium (the Flemish part), for example. On the other hand, the two regions could agree on the choice of sensor.

It is also important to bear in mind that multi-licences should be obtained for the images bought so that they can be used by each organisation. The advantage of satellite images is that they enable reliable and repeatable methods to be used for monitoring changes at the level of the protected areas.

Furthermore, the methodology developed by the Piedmont region cannot be applied as it is. It delimits polygons which may contain several different habitats. This approach therefore differs from the approach taken in the ARCH project. Adapting the method would need to be considered.

Moreover, to transfer this approach to the Nord-Pas de Calais or Kent region would mean that each park and reserve in the region would be involved in updating the maps. However, the question would then arise regarding those areas not managed by the parks or reserves: who would be responsible for producing the maps of those areas, the region?

Furthermore, in the case of transferring the method, this would require each organisation to be properly trained in order to ensure consistency between the updates produced so that the homogeneity of the existing base map is kept. Using an independent service provider or competent services in the region should be considered. The training could be undertaken jointly by each of the two regional bodies.

In the longer term, this approach has the advantage of making each management body in the region capable of doing their own updates independently, with each region being available to provide support and assistance to each management body in order to ensure the updates are consistent.

<u>The good practice in Wales</u>

The good practice developed by Wales for updating its habitat maps favoured a centralised approach. A regional public organisation specialised in the field of biodiversity protection initiated the project (the CCW). Therefore, the maps produced are owned by the CCW, but can be accessed by the different local and regional stakeholders.

The general principle of the methodology developed in Wales for updating maps relies entirely on the use of satellite images covering the whole of the country. A semi-automatic classification approach was developed for producing the updated map. More precisely, an object oriented classification approach was used. This methodology has the advantage of combining the knowledge of remote sensing experts with that of biodiversity experts (i.e. ecologists). In other words, the ecologists' knowledge is confirmed by the remote sensing data in the form of a set of rules which enable the different plant communities to be characterised.

In this approach, the methodologies and tools used required the external support of a service provider, an independent expert in geomatic sciences, to ensure the success of the project. The Nord-Pas de Calais and Kent regions would have to choose a service provider. An alternative would be to use the competent public services in the regions, if they exist, to carry out the updates. Furthermore, as was done in Wales, the Nord-Pas de Calais and Kent regions could use the French Space Agency (the CNES) and the UK Space Agency, respectively. These two agencies could provide not only their expertise, but also quality control and possibly funding.

They could also use service providers to implement the methodology. Whichever approach is preferred, a transfer of knowledge to make the region autonomous could be considered.

However, the different local stakeholders (e.g. park managers, etc.) must not be forgotten. They need to be informed about implementing the methodology (through training, presentations, etc.), and also involved in the development process during the quality control phase in order to ensure that the most is made of their local knowledge.

In addition, a major challenge will be acquiring satellite images which cover the whole region. Although this approach does not specify using one single sensor, it does however assume that images without atmospheric biases will be used, that the dates the images were taken will be close together to ensure temporal consistency (for the different phenological stages), and that they will cover different seasons so that the vegetation community phenology can be taken into account, this being one of the strong advantages of this method. In effect, acquiring satellite images of different seasons enables the seasonal variabilities of plant communities to be taken into account when classifying the habitats. It is this multi-temporal aspect which marks the difference between spatial remote sensing and the more classical CAPI methods, which can only exploit one date. One solution could be to plan when the images are taken. In this case study, the costs are higher when compared to the costs of using archive satellite images, but the dates the images are taken can be fixed. Again, a problem concerning the agility of the sensors will probably be encountered. Furthermore, the question of whether images covering the whole of the two regions can be acquired arises again. As mentioned previously, there is no VHR or HR data available which covers the whole of the two regions. From a temporal, radiometric and spectral point of view, it is however important that the images are taken on the same or very close dates (for example, from the same trajectory acquisition). Once again, programming when the images are taken is probably the best solution.

Lastly, a point which needs to be clarified is the reliability of the methodology. While it enabled Wales to produce a detailed habitat map, would it also work for the Nord-Pas de Calais and Kent regions? The habitats in these regions are more fragmented and divided than in Wales which has larger, more homogenous expanses. In addition, the environments to be found in each of the two regions are not the same. Therefore, the rules for each region need to be established first, before establishing a joint method. The method cannot therefore be transferred until an initial test phase is carried out. However, the existing base map provides an excellent base for image segmentation, which is a necessary phase in developing object oriented classifications.

The good practice in Brandenburg

The good practice developed in the Federal State of Brandenburg favours a centralised approach. The National Office for the Environment, Health and Consumer Protection, under the Ministry for the Environment, Health and Consumer Protection, employed the services of the *Luftbild Umwelt Planung GmbH* to map specific habitats (dry heaths, Biotope 4030 under the Natura 2000 nomenclature).

The methodology developed for this map was based on the use of Very High Resolution satellite images. This solution was the least expensive way to map the well delimited zones (access forbidden for security reasons) in a short space of time.

Based on a semi-automatic pixel classification, this approach involves establishing a “knowledge base” which acts as the training database for supervised classification.

While the good practice detailed in the two cases above centres on habitat mapping, the methodology developed in this example would not meet the need to update the map produced as part of the ARCH project. The approach developed in Brandenburg concentrates on one specific habitat by exploring its structure and composition. To do the same in order to reconstruct each of the habitats in the ARCH nomenclature would not be possible. However, establishing maps of habitats of specific interest is more appropriate. These ad hoc maps could enable the composition of these habitats to be identified using different indicators/types of land use for the purpose of assessing the habitats.

In terms of the future needs of users on specific habitats, this methodology could be transferred. As with Brandenburg, the region could employ the services of an external company to carry out the mapping of targeted habitats (with knowledge transfer being key) or to undertake the mapping internally if it has the capacity to do so.

However, at the moment, while the method is operational for dry heath type habitats, the potential for applying it to other habitats is not really known. An exploration phase would be required depending on the habitats of interest which could be considered.

The table in Annex 6 summarises the advantages and disadvantages of these three examples of good practice with regard to the challenges mentioned.

Annexe 1: Overview of the use of remote sensing to map Natura 2000 habitats in Europe

Austria:
Use of remote sensing for six habitats. No details known.
Other projects: Some maps were produced of the Alps national parks (Sell et al. (2004)) as part of the EON2000+ project.

Belgium:
Use of remote sensing for two habitats (codes 3260 and 7220). This was listed for mainland Europe (responsibility of the region of Wallonia). For the habitat code 3260, an existing map was used (a map of hydrographic networks) as a starting point to delimit the possible occurrence of habitat code 3260. The results for code 7220 are unclear.
Other projects: in Flanders, several pilot projects to map habitats using remote sensing in different ecosystems were carried out:

- coastal dunes: ref: Kempeneers et al. (2009);
- dry and humid marshes: Habistat Project, ref: http://habistat.vgt.vito.be;
- grasslands in valley ecosystems: cf. Chan & Paelinckx (2008);
- estuary ecosystems and cold water pools (not published).

These projects depended enormously on external funds.

Bulgaria:
No reports in 2007.
Other projects: unknown.

Cyprus:
Use of remote sensing for six habitats. No details known.
Other projects: unknown.

Denmark
Use of remote sensing for twenty-nine habitats, although still used jointly with other methods. This probably refers to the use of aerial imagery for habitat mapping (with field surveys to follow. Ref: Fredshavn (2004)).
Other projects: Interesting work has probably been carried out by NERI (www.dmu.dk). To be checked with Geoff Groom (responsible for remote sensing activities at NERI).

Estonia:
Use of remote sensing for two habitats. No details known.
Other projects: unknown (except for the SPIN Project, with some study sites. Ref: Germany).

Finland:
Use of remote sensing for twenty-five habitats. No details known. Perhaps refer to “Metsähallitus” (see below).
Other projects: “Metsähallitus” uses remote sensing for the inventory of large scale habitats in protected areas. It undoubtedly involves the development and application of interpretation guides to map habitats using infrared colour images. It is not clear whether advanced remote sensing techniques are used. The EON2000+ project had study areas in Finland. The focus was on the woodland habitat types.

France:
Use of remote sensing for two habitats. No details known.
Other projects: unknown.

Germany:
Other projects: infrared colour aerial photographs to map habitats are widely used (ref: the Arweiler et al. Interpretation key (2002)). A few States have studied the use of remote sensing to map and monitor habitats, often in cooperation with universities or private companies. Some examples are:

- Brandenburg: different projects by "Luftbild Umwelt Planung", e.g. mapping heather, marshes, etc. Ref: http://www.lup-umwelt.de/forschung-entwicklung: SARA '04, SARA-EnMap and CARE-X;
- Schleswig-Holstein: collaboration in different projects (e.g. SPIN, Geoland "Observatory for Nature Protection": http://www.gmes-geoland.info/OS/ONP/index.php);
- Bayern: many academic projects (e.g. www.winalp.info; http://www.dbu.de/stipendien_20004/711_db.html).

For further information on the SPIN project (which includes test sites in Germany, the United Kingdom, Greece and Estonia, amongst others) see the special edition of the "Journal for Nature Conservation" (Vol. 13, issue 2-3).

Greece:
Other projects: some study sites as part of the SPIN project (ref: Alexandridis et al. (2009)) for the study on using remote sensing for updating maps of the Natura 2000 habitats.

Hungary:
Use of remote sensing for three habitats. No details known.
Other projects: unknown.

Ireland:
Use of remote sensing for twelve habitats (1140, 1310, 1320, 1330, 1410, 3180, 4010, 4030, 6210, 6230, 7130, 8240). The supporting documents provide further details on the methods used. See: http://www.npws.ie/en/PublicationsLiterature/ConservationStatusReport/Habitats/. In the main, interpretation of aerial photographs was used. A less complex method was used for limestone pavements (8240) only.
Other projects: A number of pilot projects was carried out using Lidar (raised bogs) and Very High Resolution satellite imagery (uplands), with varied success (Contact: Gemma Weir at NPWS).

Italy:
Use of remote sensing for fifty-eight habitats. However, no details could be found.
Other projects:
A few projects in the alpine regions:

- the Interreg IIIA Alcotra Project "Management and conservation of the habitats and flora in the South-West of the Alps" (by IPLA spa);
- work by the "Institute for Applied Remote Sensing" (Bolzano): http://www.eurac.edu/staff/MZebisch/default.html.

In addition, the "Carta della Natura" Project uses supervised classification from Landsat satellite images, followed by manual adjustment if necessary. Ref: http://www.apat.gov.it/site/it-IT/Progetti/Carta_della_Natura/ and Amadei et al. (2004).

Latvia:
Use of remote sensing for fifteen habitats.
The "Latvian Fund for Nature" has used supervised classification on Landsat ETM+ images for general information on land use (for the preparation of the Natura 2000 standard data form) and for a more detailed classification of vegetation in a number of Natura 2000 sites. Visual photo-interpretation of images is frequently used (contact person: Ainars Aunin, LDF).

Lithuania:
Use of remote sensing for thirteen habitats. No details known.
Other projects: unknown.

Luxembourg:
Use of remote sensing for four habitats, but the remote sensing in fact refers to an existing map of land use (Biophysical Land Observation), produced using aerial and satellite imagery and updated using field observations (contact person: Sandra Cellina, Ministry for the Environment).

Malta:
Other projects: unknown.

The Netherlands:
Other projects:
The Netherlands have a long tradition of researching the use of remote sensing for monitoring biodiversity using different methods and in different environments (e.g. tidal marshes, heather, coastal dunes and flooded grasslands). The "Centre for Geo-Information of Alterra" is very active in this area (contact person: Sander Mücher, sander.mucher@wur.nl). Their research interests extend to the European and indeed international level (e.g. the FP7 EBONE Project: www.ebone.wur.nl).

Poland:
Use of remote sensing for eight habitats. No details known.
Other projects: unknown.

Portugal:
Use of remote sensing for seven habitats. No details known.
Other projects: unknown.

Romania:
Other projects: several remote sensing projects are underway, essentially related to the Natura 2000 mapping, but no details are currently known.

Spain:
Use of remote sensing for twenty-six habitats. This refers to the photo-interpretation of aerial images to map vegetation (contact person: David Galicia Herbada, TRAGSA).
Other projects: Remote sensing was used to map habitats in the "Picos de Europa": Diaz Varela et al. (2008).

Slovakia:
Other projects: unknown.

Slovenia:
Other projects: unknown.

Sweden:
Use of remote sensing for twenty-seven habitats. This refers to the base inventory ("*Basinventering*"), which used the photo-interpretation of infrared colour aerial images to map habitats in the country (ref: interpretation guide on their website). For a limited number of habitats and mainly in the mountainous regions, the classification of satellite images was used (contact person: Birgitta Olsson, Metria).
http://swenviro.naturvardsverket.se/dokument/epi/basinventering/basinvent.htm and
http://swenviro.naturvardsverket.se/dokument/epi/basinventering/basdok/pdfer/Flygbildstolkningsmanualen_version_71_slutgiltig_komplett.pdf
Other projects:
Sweden has an inventory of its landscapes covering the whole of the country which supports the monitoring of biodiversity and the condition of the countryside.
The programme uses the photo-interpretation of aerial images on samples of the land, amongst others (ref: http://nils.slu.se on NILS and the photo-interpretation of aerial images).

United Kingdom:
Use of remote sensing for three habitats. No details known.
Wales has a habitat map produced using remote sensing. Further information can be obtained from the Countryside Council of Wales (contact person: Alan Brown).
The EON2000+ Project studied areas in Scotland (with the "Scottish Natural Heritage" as a local partner). The focus was on woodland habitat types.

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Annex 2: Summary of the meeting with INBO and VITO – two Flemish organisations working with natural habitats

Summary of the meeting on 30 March 2011 with INBO (Research Institute for Nature and Forests) and VITO (Flemish Technological Research Institute), two Flemish organisations working with natural habitats. The meeting took place at the INBO offices in Brussels.

The participants were:

- Birgen Haest - VITO (birgen.haest@vito.be)
- Desiré Paelinckx - INBO (desire.paelinckx@inbo.be)
- Gerald Louette - INBO (gerald.louette@inbo.be)
- Toon Spanhove - INBO (toon.spanhove@inbo.be)
- Jeroen Vanden Borre - INBO (jeroen.vandenborre@inbo.be)
- Guido Peroni - SIRS
- Alexandre Pennec - SIRS

The following points were discussed:

- Presentation of the different companies and institutes: INBO, VITO and SIRS. INBO and VITO are involved in the HABISTAT project. INBO was also responsible for establishing the "Flemish ecological map". This map was produced during 1997 and 2008 from field work. INBO is now considering updating the map. For the moment the methodology has not been decided on (CAPI, semi-automatic methods, etc.). In this respect, they regard the work carried out under the ARCH Project to be interesting and promising. Furthermore, semi-automisation tests have been carried out on different areas without producing conclusive results (except for on forested areas).

- Presentation of the work carried out by the INBO and VITO teams as part of the HABISTAT project: "From hyperspectral images to Natura 2000 habitat patches and quality indicator maps results from the HABISTAT project". The work was on mapping natural habitats, more precisely heathland habitat types, over a study area of 10 km^2 using hyperspectral data (from airborne sensors of 24 cm spatial resolution). The technology only offered real promise at the local level on specific habitats. It could not be considered operational at the regional level for mapping natural habitats. Up until now, work has only been carried out on one given habitat. Work was undertaken to extend the methodology to other habitats but this is still at the research stage.

- Discussion on the different European projects known to INBO/VITO and SIRS which are using remote sensing to monitor natural habitats and biodiversity. In particular, the three projects analysed in the report on Mission 2 were mentioned, as well as:
  - The MS.MONINA European project (FP7-Space_2010): "An integrated multi-scale EO-based monitoring service as European contribution to sustainable global diversity" which began this year and which both INBO and VITO are participating in. This project aims to develop remote sensing projects in the context of Natura 2000. The project will be carried out at three levels: European – Member State – Local. The idea is to develop services to assist the different competent public authorities.

  - The European ENCA network which works in nature conservation at European level. Within this network, a working group is specifically interested in monitoring habitats by integrating remote sensing technologies with field work. A workshop was held in Andalusia on 10 and 11 May this year on "Integrating image training data and ground-truth data with field survey on Natura 2000 sites".

In conclusion, it became more and more evident that the ARCH project is a pioneer in the field of mapping semi-natural habitats and biodiversity at a regional level.

Annex 3: Summary of the Habistat workshop

Source: http://habistat.vgt.vito.be

Context: monitoring biological diversity in Europe "after 2010"

The aim of the year 2010 (the Year of Biodiversity) was to establish the status of biodiversity loss. This work is far from done. A new strategy "after 2010" for biodiversity in Europe is currently being discussed. This new strategy will not only consider conservation (e.g. Natura 2000), but will also concern the role of ecosystems and the services they provide.

A crucial point in terms of this strategy being implemented successfully is our capacity to establish a scientific reference level on the status of biodiversity in Europe and to measure the progress made towards achieving the objectives. However, acquiring exact and recent information on biodiversity, whether at local, Member Sate or European level remains a huge challenge, as demonstrated in the last report on the conservation status of species and Natura habitats between 2000 and 2007.

Remote sensing has been recognised as a powerful and innovative tool, but its use for monitoring biodiversity remains dispersed and limited. The aim of this workshop is to demonstrate examples of good practice of using remote sensing for creating an inventory of and monitoring biodiversity in Europe.

Particular attention has been given to the opportunities provided by remote sensing for assessing the status of conservation of the Natura 2000 habitats, for assessing the suitability of the habitat for Natura 2000 species and for evaluating ecosystems.

During the closing plenary session, recommendations were made with regard to how remote sensing could contribute to an operational system for monitoring biodiversity, which should enable a scientific reference level on the status of biodiversity to be established, and the progress made in achieving the biodiversity targets in Europe by 2020 to be measured.

What is HABISTAT?

It is a framework for classifying the status of habitats (HABItat STATus) mapped using remote sensing methods.

The HABISTAT project intends to develop an "operational", oriented methodology for mapping, monitoring and evaluating the characteristics of vegetation and habitats with the aim of determining the conservation status of the habitat.

The aim of the project is to create a transferable platform for "operationally" mapping habitats by integrating new advanced remote sensing methods. The new techniques which are used in the project include hyperspectral imagery, reconstructing Very High Resolution images, automatic classification, contextual spatial description and structural analysis.

A major application for integrating and validating the developed methodologies is the mapping and evaluating the conservation status of the Natura 2000 habitats.

Workshop objectives:

By studying the weaknesses of the current remote sensing habitat maps, the aim of this project is to improve the classification framework and to create a transferable platform which integrates the new advanced remote sensing methodologies, developed especially for "operational" habitat maps.

Work carried out in the previous Habistat project focused on maps of vegetation species based solely on their spectral signature. In this work, the classification framework was extended with the introduction of spatial aspects to the classification process. The resulting characteristics could supplement the spectral characteristics, or they could compensate for a lack of detailed spectral information.

The remote sensing of vegetation is extremely complex. Many parameters influence the spectral signature of the canopy. Parameters such as atmosphere, and also biophysical parameters such as the leaf area index, the distribution of the angles of the leaves and the observation geometry all have an impact. An analysis of these parameters will be undertaken and a multi-resolution approach has been presented to recover more solid characteristics. A better understanding of the impact of the scale of study, of the resolution, and of the temporal series on classifying ecotopes could lead to more cost-effective approaches.

Deeper exploration of the link between the different scales:

- Leaf – canopy – top of the atmosphere

and

- airborne imagery and coarser satellite data (e.g. Chris-Proba 18 m)

is also desired.

Thirdly, this project will use the latest algorithms for reconstructing Very High Resolution images to reduce the spatial resolution variance between airborne hyperspectal data and spatial data. These algorithms were designed to obtain a high resolution image from several low resolution images. These techniques have existed for decades, but have gained interest due to the proliferation and improvements of digital technology in different fields such as medical imaging, satellite imagery, video surveillance, etc. The potential of these algorithms for hyperspectral imagery as well as the information gain from Very High Resolution images will be analysed for use in classifying ecotopes.

To improve the classification accuracy and to strengthen an operational classification oriented chain, the fourth objective is to investigate the operational potential of automatic classifications from the point of view of stability, precision, usability and IT costs.

The fifth objective is to present a structural analysis for using the diversity of vegetation types to better identify and establish the link to the degree of development of habitats.

The final objective is to integrate and validate the methodologies developed using the “Belgium Biological Valuation Map” and the chosen habitats which are classed as “priority” under Natura 2000.

Conclusions from the workshop:

This workshop demonstrated many successful and less successful examples of using remote sensing in monitoring biodiversity.

It appears that success was achieved when:

- The problem is specific and well-defined. It is impossible to resolve all user needs immediately. If the objectives are too vague or too wide, then concentration on the actual problem is hindered.

- The future users (the ecologist/naturalist community) and the producers (the remote sensing community) are communicated with and they cooperate in the project from the beginning to develop the most effective approach to the problem. Ecological knowledge is vital in the first phases of the project.

Operational methods exist, but their application on a larger scale is often hampered by the lack of suitable image data available. The participants greatly welcomed the policy of more open access to satellite data adopted by the GMES and encourage the European Community to:

- develop in parallel a facility for accessing the airborne sensors in Europe;
- ensure the continuity of data in terms of long temporal sets of similar types of data, given that these are essential for long-term monitoring.

Over the last few years, remote sensing and biodiversity stakeholders have worked closer together and have increased their exchanges of experience and discussions, but essentially as part of short-term projects. There is a clear need to pursue a dialogue between the two communities, preferably under a formal framework with secure funding.

Standardising the remote sensing methodologies over larger regions and longer periods may seem to be logical, but there is a risk in making the system too rigid and less adaptable to more specific situations, and to advancing the understanding of the concepts over time.

Rather than promote the standard methods of processing and extracting information from remote sensing data, there is a need to develop frameworks which enable results to be compared in space and in time (by upscaling) and/or by reworking basic measures (“initial data”, regardless of the variability of the sensors, the thematic legends and the processing methods used.

This need should receive more attention from the scientific community and the geoinformatics community should be involved.

Annex 4: List of habitats mapped by both the Alcotra project and the ARCH project

Piedmont habitats		ARCH habitats	
Code	Title	Code	Title
22000000	Standing fresh waters	221	Eaux Douces
22200000	Unvegetated muds or shingles	222	Galets ou vasières non végétalisées
22300000	Amphibious communities	223	Communautés amphibies
22400000	Aquatic vegetation	224	Végétation aquatique
24400000	Submerged river vegetation	244	Végatation immergée des rivières
24520000	Euro-siberian annual river mud communities	245	Dépôts d'alluvions fluviatiles limoneuses
31200000	Dry heaths	312	Landes sèches
31810000	Medio-European rich-soil thickets	318	Fourrés
31820000	Box thickets		
31840000	Broom fields		
31860000	Bracken fields		
31870000	Woodland clearings		
31880000	Common juniper scrub		
318C0000	Hazel thickets		
34110000	Middle european rock debris swards	34	Steppes et prairies calcaires sèches
34300000	Dense perennial grasslands and middle european steppes		
34310000	Sub-continental steppic grasslands		
34320000	Sub-atlantic semi-dry calcareous grasslands		
34330000	Sub-atlantic very dry calcareous grasslands		
34400000	Thermophile forest fringes		
34700000	Mediterraneo-montane grasslands		
35100000	Atlantic mat-grass swards and related communities	35	Prairies siliceuses sèches
35200000	Medio-european open siliceous grasslands		
37100000	Meadowsweet stands and related communities	37A/37B	Lisières humides à grandes herbes/Prairies humides
37200000	Eutrophic humid grasslands		
37240000	Flood swards and related communities		
37300000	Oligotrophic humid grasslands		
37310000	Purple moorgrass meadows and related communities		
37320000	Heath rush meadows and humid mat-grass swards		
37700000	Humid tall herb fringes		
37800000	Subalpine and alpine tall herb communities		
37880000	Alpine dock communities		
38000000	Mesophile grasslands	38	Prairies mésophiles

38100000	Mesophile pastures	381	Pâtures mésophiles
38200000	Lowland hay meadows	382	Prairies à fourrages des plaines
41100000	Beech forests	41	Forêts caducifoliées
41110000	Central European acidophilous beech forests with woodrush Luzulo-Fagenion		
41130000	Neutrophilous beech forests		
41150000	Subalpine beech woods		
41160000	Beech forests on limestone		
41280000	Southern alpine oak-hornbeam forests		
41390000	Post cultural ash woods		
41400000	Mixed ravine and slope forests		
41500000	Acidophilous oak forests		
41700000	Termophilous and supra-mediterranean oak woods		
41800000	Hop-hornbeam, oriental hornbeam and mixed thermophilous forests		
41900000	Chestnut woods		
41B00000	Birch woods		
41D00000	Aspen woods		
41H00000	Other deciduous woods		
41H10000	Locust tree plantation		
44111000	Willow-tamarisk brush	44	Forêts riveraines, forêts et fourrés très humides
44112000	Willow and sea-buckthorn brush		
44120000	Lowland, collinar and mediterraneo-montane willow brush		
44130000	White willow gallery forests		
44200000	Grey alder galleries		
44300000	Medio-European stream ash-alder woods		
44440000	Po oak-ash-alder forests		
44614000	Italian poplar galleries		
44910000	Alder swamp woods		
44920000	Mire willow scrub		
51100000	Near-natural raised bogs	51	Tourbières hautes
51200000	Purple moorgrass bogs		
53100000	Reed beds	53	Végétation de ceinture des bords des eaux
53200000	Large sedge communities		
53210000	Large Carex beds		
53220000	Tall galingale beds		
53300000	Fen-sedge beds		
54100000	Springs	54	Bas marais, tourbières de transition, sources
54110000	Soft water springs		
54120000	Hard water springs		
54200000	Rich fens		
54300000	Arcto-alpine riverine swards		

54400000	Acidic fens		
54500000	Transition mires		
54600000	White beak-sedge communities		
64400000	Fluviatile dunes	643	Dunes paléo-côtières
81000000	Improved grasslands	81	Prairies améliorées
82000000	Crops	82	Cultures
83300000	Plantations	833	Plantations indeterminées
83310000	Conifer plantations	8331	Plantations de conifères
83320000	Plantations of broad-leaved trees	83321	Plantations de peupliers
84100000	Tree lines	84H	Haies, alignements d'arbres
85000000	Urban parks and large gardens	85	Parcs urbains et grands jardins
86000000	Towns, villages, industrial sites	86	Villes, villages et sites industriels
86410000	Quarries	8641	Carrières abandonnées
86420000	Slag heaps and others detritus heaps	8642A/8642B	Terrils nus et boisés
87100000	Fallow fields	87	Friches
87200000	Ruderal communities		
89220000	Ditches and small canals	89	Lagunes et réservoirs industriels

Annex 5: List of habitats mapped by both Wales and the ARCH project

Habitats in Wales			CORINE Biotopes correspondence		ARCH habitats	
Code	English title	French title	Code	Title	Code	Title
A1.1.1	Semi-Natural broadleaved woodland	Forêt de feuillus semi-naturelle	41	Forêts caducifoliées	41	Forêts caducifoliées
A1.1.2	Planted broadleaved woodland	Forêt de feuillus plantée	83.32	Plantations d'arbres feuillus	83321	Plantations de peupliers
A1.2.2	Planted coniferous woodland	Forêt de conifères plantée	8331	Plantations de conifères	8331	Plantations de conifères
A2.1	Dense scrub	Fourré dense	318	Fourrés	318	Fourrés
A2.2	Scattered scrub	Fourré clairsemé				
B1.1	Unimproved acid grassland	Prairie acide non améliorée	35/36	Prairies siliceuses sèches/Pelouses alpines et subalpines	35	Prairies siliceuses sèches
B1.2	Semi-improved acid grassland	Prairie acide semi-améliorée				
B2.1	Unimproved neutral grassland	Prairie neutre non améliorée	38	Prairies mésophiles	38	Prairies mésophiles
B2.2	Semi-improved neutral grassland	Prairie neutre semi-améliorée				
B3.1	Unimproved calcareous grassland	Prairie calcaire non améliorée	34.3216	(Steppes et prairies calcaires sèches)	34	Steppes et prairies mésophiles
B3.2	Semi-improved calcareous grassland	Prairie calcaire semi-améliorée	34.21	(Steppes et prairies calcaires sèches)	34	Steppes et prairies mésophiles
B4	Improved grassland	Prairie améliorée	81	Prairies améliorées	81	Prairies améliorées
B5	Marshy grassland	Prairie marécageuse	37B	Prairies humides	37B	Prairies humides
B5.1	Marshy grassland Juncus-dominated	Prairie marécageuse à dominante Juncus	15.33A	Zones à Juncus Maritumus	15	Marais salés, prés salés (schorres), steppes salées et fourrés sur gypse
C1.1	Bracken	Fougère	31.86	Landes à fougères	318	Fourrés
C1.2	Scattered bracken	Fougère clairsemée				
C3.1	Tall ruderal herb	Haute herbe rudérale	87	Friches	87	Friches
D1.1	Dry acid heath	Lande sèche acide	312	Landes sèches	312	Landes sèches
D1.2	Dry basic heath	Lande sèche alcaline				
D1.3	Scattered dry heath	Lande sèche dispersée				
D2	Wet heath	Lande humide	311	Landes humides	311	Landes humides
D3	Lichen/bryophyte heath	Lande de lichen/bryophyte	31.2125		312	Landes sèches
E1.6.1	Blanket bog	Tourbière de couverture	52	Tourbière de couverture	52	Tourbière de couverture
E1.6.2	Raised bog	Tourbière haute	51	Tourbière haute	51	Tourbière haute
E2	Flush and spring	Source et ruissellement	54.1	Sources	54	Bas marais, tourbières de transition, sources
E2.3	Bryophyte-dominated spring	Source à dominante bryophyte	54.111	Sources d'eaux douces à Bryophytes	54	Bas marais, tourbières de transition, sources
E3.2	Basin mire	Bourbe de bassin	22.3	Communautés amphibies ("bassins vaseux")	223	Communautés amphibies
E3.2.1	Modified basin mire	Bourbe de bassin modifiée				
E3.3	Flood-plain mire	Bourbe de plaine inondable	245	Dépôts d'alluvions fluviatiles limoneuses	245	Dépôts d'alluvions fluviatiles limoneuses
E3.3.1	Modified flood plain mire	Bourbe de plaine inondable modifiée				
F2.2	Inundation vegetation	Végétation des zones inondables	44	Forêts riveraines, forêts et fourrés très humides	44	Forêts riveraines, forêts et fourrés très humides
G1	Standing water	Eau stagnante	221	Eaux douces	221	Eaux douces
G2	Running water	Eau courante	24	Eau courante	24	Eau courante

H1.1	Intertidal mud/sand	Boue/sable sur zone intertidale	14	Vasières et bancs de sable sans végétation	14	Vasières et bancs de sable sans végétation
H1.2	Intertidal cobbles/shingle	Pavé/galet sur zone intertidale	171	Plages de galets sans végétation	171	Plages de galets sans végétation
H1.3	Intertidal rocks/boulders	Roches/rochers sur zone intertidale	18.11	Rochers et falaises de la fange médiolittorale	18	Falaises maritimes
H2.4	Scattered salt marsh plants	Plantes de prés salés dispersées			15	Marais salés, prés salés (schorres), steppes salées et fourrés sur gypse
H2.6	Salt mash	Prés salés	15	Marais salés, prés salés (schorres), steppes salées et fourrés sur gypse	15	Marais salés, prés salés (schorres), steppes salées et fourrés sur gypse
H3.1	Mud/sand above mhw	Boue/sable au-dessus nme	161	Plages de sables	161	Plages de sables
H3.2	Shingle/gravel above mhw	Galet/gravier au-dessus nme	171	Plages de galets sans végétation	171	Plages de galets sans végétation
H4	Rocks/boulders above mhw	Roches/rochers au-dessus nme	18.13/18.16	Rochers de l'étage médiolittoral supérieur/supralittoral	18	Falaises maritimes
H6.4	Dune slack	Panne dunaire	163	Lettes dunaires humides	163	Lettes dunaires humides
H6.7	Dune scrub	Fourré sur dune	162A	Dunes avec fourrés, bosquets	162A	Dunes avec fourrés, bosquets
H6.8	Open dune	Dune ouverte	162	Dunes	162	Dunes
H8.1	Hard cliff	Falaise dur	18	Falaises maritimes	18	Falaises maritimes
H8.2	Soft cliff	Falaise douce				
H8.4	Coastal grassland	Prairie côtière			15	Marais salés, prés salés (schorres), steppes salées et fourrés sur gypse
I2.1	Quarry	Carrière	863C/8641	Carrières en activité/Carrières abandonnées	863C/8641	Carrières en activité/Carrières abandonnées
J1.5	Gardens	Jardins	85	Parcs urbains et grands jardins	85	Parcs urbains et grands jardins
J3.6	Buildings	Bâtiments	86	Villes, villages et sites industriels	86	Villes, villages et sites industriels
J3.7	Track	Route	991	Réseau routier	991	Réseau routier

Annex 6: Summary table of the advantages and disadvantages of the three examples of good practice

Good practice	Advantages	Disadvantages
Piedmont	• Involvement of local administrations to ensure better management. • Involvement of the IPLA, an independent and neutral source of multi-disciplinary expertise. • Use of satellite images particularly important for regional authorities as they enable reliable and repeatable methods to be applied. • Use of satellite data enabled cost savings, particularly when the purchase and use are shared. • Use of satellite imagery for a significantly large territory (enabled greater continuity in the quality of the image). • Gained time in implementing the methodology. • The methodology enabled the habitats and plant communities to be delimited and mapped with a greater degree of accuracy and precision. • The use of spectral information in the near infrared enabled a particularly precise and detailed map of the different plant communities to be produced. • The methodology enabled the habitats to be classified in accordance with the CORINE Biotopes and Natura 2000 nomenclatures.	• The methodology is only applicable at the level of protected sites and areas by local bodies, and not at a global level by central bodies. • The methodology uses only CAPI to determine the geometry, which requires a lot of field work (thematic information) and a lot of work to amalgamate the vectoral database. • Not all of the territory is covered because only the management bodies of parks and reserves are responsible for creating the maps.
Wales	• Support from the UK Space Agency was crucial to the project as they not only provided expertise, quality control and funding, but they also employed the service providers. • Involvement of the staff in the regional offices in the quality control phase of the map updating. • Organised stages to help everyone understand the choice of method. • Buying archive images in order to manage the budgets and check the quality of the images before buying. • Less financial investment in relation to the previous version, particularly by reducing field work.	The multi-sensor and multi-date approach makes the pre-processing phase much longer. The establishment of long and delicate rules. "Uncertainty" connected with a new way of working. The transition from a habitat map based on field surveys to a vector map derived from satellite imagery.

	• Using satellite imagery on a rather large territory enabled greater continuity in the image quality. • The methodology enabled the knowledge of ecologists on the characteristics of the different communities to be taken into account when developing the rules. • The methodology enabled habitats to be mapped and classified with greater precision and detail, and in a more exhaustive way. • Once established, the methodology enabled rapid and cost-effective updates. • Took the knowledge and expertise of ecologists and remote sensing experts into account. • The multi-temporal approach enabled the seasonal variability of plant communities to be taken into account when classifying habitats.	
Brandenburg	• The use of satellite imagery enabled information to be acquired on the protected sites located in the areas which are inaccessible for field work. • Acquiring satellite images was more cost-effective than acquiring aerial images for the relatively small and dispersed areas.	• The methodology developed is only applicable to VHR satellite images. • At the moment the methodology is only defined for dry heath habitats. • Unreliability of the availability and continuity of QuickBird images. • Quality control for the data produced is difficult. • The approach only concentrates on one specific habitat for assessment and monitoring purposes and not on mapping the whole habitat. • Robustness of the method during transition from one scene to another is not certain. • The different angles and dates the images were taken are problematic because it entails transposing the rules from one scene to another (vegetation community phenology).