**NordLaM (Nordic Landscape Monitoring)**

**Workshop on Integration of Partial Coverage and Full Coverage Landscape Monitoring Information**

23 – 24 October 2000. Tune AgroForum, Tune, Denmark.

Participants :

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| Pia Frederiksen | National Environmental Research Institute, Denmark |
| Roy Haines-Young | Centre for Ecology and Hydrology, UK & University of Nottingham |
| Thomas Wrbka | University of Vienna |
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## 1. Background and aims of the workshop

The workshop was convened as one of a series of activities under the umbrella of the NordLaM project (1999-2003). The objective of NordLaM is to develop the use of Earth observation (EO) image data in strategic (i.e. national and regional) programmes of landscape level monitoring (LLM) for the Nordic countries. NordLaM deliverables, to the Nordic Council of Ministers, include presentations on the state-of-the-art in the Nordic countries and elsewhere, reports of meetings and demonstrations focused on specific LLM issues and recommendations for LLM methods, standards and protocols for future use across the Nordic countries. Seven LLM issues, relating to the use of EO have been identified for NordLaM project focus during the period 2000-2002. One of these, that concerning the integrated use in LLM of partial and full coverage information was the subject for this workshop.

In LLM activities within the Nordic countries, as elsewhere, some landscape monitoring is based upon sample data whilst other uses data of the full extent of an area. The information contents of the types of resulting data typically differ considerably. Partial coverage LLM typically provides very detailed, precise and accurate information for the sample areas, whilst full coverage (‘census’) data is typically thematically far poorer and also possibly less precise and accurate. However,

in many cases programmes for providing the types of LLM information now needed for sustainable environment and biodiversity management and related research work need to integrate partial and full coverage LLM data. Indeed, in a number of cases it has been found that such integration results in new capabilities for LLM that are 'greater than the sum of the parts'.

The aim of this workshop was to examine the possibilities for combining partial and full coverage LLM data, in terms of both the needs and objectives for such integration and the technical requirements and methods for achieving such integration. In terms of the NordLaM project, the aim was also to identify relevant ways of developing this topic.

## 2. Presentation of landscape level monitoring in Austria – Thomas Wrbka.

There is no single LLM programme in Austria, but three individual projects together fulfill the concept of LLM :
SINUS (96-00) addresses LLM in terms of landscape structure
BINKL (98-01) addresses LLM in terms of bio-indicators
LANDLEBEN (00-02) examines LLM with respect to biodiversity assessment and farming.

SINUS is based upon Forman principles of a landscape as 'a repeated spatial pattern of landscape elements', e.g. 'scattered patch landscape', ' corridor dominated landscape', ' chequerboard pattern landscape', 'network pattern landscape'. As such, two major tasks under SINUS were to (a) identify and (b) delinate the major Austrian landscape types. Automated segmentation and rule-based visual interpretation of Landsat TM images were used to achieve these tasks. The key criteria for this were homogeneity of land cover and landscape structure. Elements were then classified in terms of the dominant landuse system and dominant landforms present. This produced a national map of Cultural Landscape Types (CLT), with 12 Types and 37 Subtypes.

A stratified random sampling was seen as particularly appropriate for LLM in Austria due to the high landscape diversity. The national map of CLT was intersected with national maps of elevation and geology and isoclustering used to produce an 8 class stratification. 5x5 km sample areas were chosen as 10 random per stratum, plus a further 20 subjectively selected areas; two paired 1x1 km sites were selected within each sample area for the actual field survey. The 200 1x1 km sites were surveyed in terms of land use, patch origins, a matrix/patch/corridor model, hemerobiotic state and species richness (5 person-days per site). The database from this survey work has been used for analysis of functional landscape types (' Funlands'), integrating the different attributes.

BINKL explores possibilities for bioindication of sustainable agriculture, by means of human impact sensitive species (vascular plants, birds and bryophytes), based upon 40 of the SINUS survey sites. These areas have been examined in terms of their Funlands characterisation. The aim has been to find indicator species for specific landscape types.

LANDLEBEN incorporates socio-economic data into the framework of SINUS and BINKL. Owing to the nature of much socio-economic data the sample areas, although lying coincident with those of SINUS, are far larger. Methods include interviews with farmers, elboration of farm styles and identification of driving forces for landscape change, enabling integration of biotic data and socio-economic data at the farm level.

## 3. Statistical approaches to the integration of partial and full coverage monitoring information : experiences in forestry – Michael Köhl

Official statistics on landscape attributes, such as national estimates of forest coverage can be mis-leading. However, statistics, like maps, are highly desirable outputs. In simple terms, satellite images provide a basis for maps, while sample surveys provide a basis for statistics. But, sample surveys can also be used to make maps and images used to provide statistics, and both can be combined to provide either maps or statistics. The need for more sophisticated methods of generating maps and statistics from images and sample surveys was illustrated by the situation faced by the Swiss NFI between the mid-1980s and mid-1990s. This period saw an increase from 400 to 600 in the number of attributes to monitor but a decrease from 11 Mio CHF to 8 Mio CHF in the funding for the work. Understanding the characteristics of monitoring attributes is essential. This includes understanding methods of assessment and scale (nominal, ordinal, interval, absolute). Attributes may also relate to aspects of timber production, non-wood goods and services and landscape. The focus (vertical and horizontal aggregation) for the survey also needs to be considered.

With these points in mind, a typology of methods for integration of partial and full coverage monitoring information was presented :

1a. Derivation of maps from satellite images – a basic single-phase operation.
1b. Derivation of statistics from sample surveys – a basic single-phase operation. An important aspect of this operation is that an inference about the reality is made from the results of data sample data assessment and analysis.
1c. Combined surveys, such as stratified sampling, represent slightly more complex single-phase methods for deriving an estimate for a population, e.g. using a satellite image as a basis for a class map of homogeneous strata.
2. Multi-phase sampling involves integration of a dense grid of samples with basic attribute information with a less dense grid of more detailed attribute information. Important extra knowledge on the error components involved can be added, but at the cost of greater effort.
3. Full (image) and partial (sample) coverage information may also be integrated to derive a map output. This is the approach of the kNN-method, with attributes estimated from the spectral (i.e. image data) distance to locations with field sampled data. The classical kNN method requires attributes to be expressed as mean values, but later extensions enable its application with attributes that are expressed only categorically.
4. Derivation of a map from sample data involves use of geo-statistical methods, such as semivariance analysis and use of a variogram for interpolation, as in kriging.
5. A final possibility is that of going from image data directly to statistics. In its simplest form, the problem here is too few attributes can be assessed from either satellite images or air photographs. An alternative is the use of landscape indices.

These can be calculated in various ways, such as by use of ‘ moving windows’ across the the image. Problems associated with such indices are that they can be difficult to interpret and can operate non-linearly depending upon e.g. whether the area comprises many edges or a matrix structure. Adaptive moving windows have, in experimental demonstrations by MK, indicated interesting possibilities.

Two final points :

1. In any monitoring situation, a decision has to be made between the safe, operational integration methods and the less tested, experimental methods.
2. “ It is easy to lie with statistics – but it is even easier to lie without” – G.P.Patil

Comments and questions :

1. MK: Optimisation of the survey represents a balance between costs and precision.
2. NN: There are significant problems in the multi-variate regression approach for estimation, associated with the different regressions found for each attribute and each area over which they are to be estimated.
3. RHY: What about the error terms involved in the different integration approaches, such as assessment errors and model errors ? MK: yes, an error budget study should be undertaken whenever possible. NN: A census layer can serve as an auxillary information layer to reduce error terms in the estimation.
4. BB: Producing a map of habitat types as part of an integrtation stategy may not be a good solution to the question being asked, since in some cases there are fundamental problems associated with expressing natural attributes as maps.

## 4. Monitoring the ‘unobservable’ – Roy Haines-Young

The fundamental issue is one of ‘ how can we combine the synoptic view of land cover derived from remotely sensed imagery with field-based survey data to model conditions in the wider countryside?’ The GB Countryside Survey (CS) of 1990 and 2000 have implemented various methods to solve this. Underlying key aspects of CS are (a) maintenance of continuity of the data series and (b) environmental stratification of ‘unchanging’ environmental parameters. The basic CS structure of stratified random samples provides a basis for statistical estimates for large areas. Both CS1990 and CS2000 have also involved production of a census land cover map from satellite images. For CS2000 this was produced as a ‘per-parcel’ rather than a ‘per-pixel’ map. The per-parcel approach was seen as providing a more believable, object-based representation of landscape objects. At the same time it provided higher spatial resolution information than the field survey side of CS could by itself. Integration of FS and LCM sample and census layers has been produced as the Countryside Information System (CIS) desktop-PC package of 1x1 km summary CS data.

The CS provides a structure for integrating sample and census data rather than a fully integrated systed. Some fundamental issues remain unresolved:

1. How should the two independent estimates of stock be calibrated, such as is required to link the CS2000 Field Survey and LCM2000 at the UK BAP ‘Broad Habitats’? At what spatial scale (level of aggregation) should calibration functions be derived – 1x1 km.sq,? county?

2. How should attribute data for the field survey polygons be handled? – by classical accounting model methods or by use of simultaneous equations?
3. How should error terms be calculated and presented?
4. Is it also possible to assign attribute data derived from the images to the FS objects? – this might involve a 3-stage integration process.

Key questions for this type of integration work are:
1. At what scale is calibration / linakge appropriate?
2. Can the integration process be reversed?
3. How are uncertainties handled?
4. To what extent can the data users drive the integration process within a system such as the CIS?

Some major sticking points for development of the CS integration are that:
1. Linkage of the CS sample and census layers essentially involved 'taking 2 independent estimates of objects in the countryside and deriving a third'.
2. Satellite image derived LC maps tend to be 'cartoons of the landscape'
3. Making map based estimates of objects at the local level is a major hurdle
4. Calibration of two independent image derived estimates of stock, such as for change assessment, is problematic.

Comments and questions :
1. RHY: the stratification of the CS differs rather fundamentally from that of the SINUS work in Austria in that it does not make use of image analysis as part of the stratification process.
2. RHY: Three types of audience are being addressed by monitoring work : the scientific communities, the policy making communities and the public awareness and campaigning comminities.
3. RHY: Possibly, integration methods should start out from having a clear goal-orientated focus.

## 5. Points from the presentations and follow-up discusssions

Four aspects of the 'partial – full information integration' (PFII) topic were used as a framework for summarising the significant issues raised by the presentations. These four aspects were :

i) The applied framework for undertaking PFII as part of LLM
ii) Major methodological issues of how PFII should be undertaken
iii) Aspects of the form and use of partial coverage information in integrations with full coverage information
iv) Aspects of the form and use of full coverage information in integration with partial coverage information.

The points noted by participants, arranged in terms of these four aspects are shown in Table 1. (Points within each box are not written in any particular order.)

Table 1.

| **(i) Applied Framework** | **(ii) Methodological Issues** |
|---|---|
| a) the ability to make estimates at the local level – this is for example particularly important for the Danish NFI<br>b) the opportunities presented by PFII for broad env./ecol. issues such as Nature Quality are important.<br>c) PFII is part of the primary need for information in order to answer the What, Where & Why of landscape and environment and for prediction via modelling.<br>d) the framework for formulating PFII must include review of user needs for LLM information, including European -vs- National needs and the needs of scientific, policy-making and public communities.<br>e) the development of PFII should be combined with developments in the use of indicators as a cost effective approach for LLM. | a) optimisation of the use of data as a whole is crucial – this includes issues of survey design and the reliability of results<br>b) issues of natural variability and scales are crucial in developing PFII methods<br>c) importance of a clear typology of integration methods, with clear links to the required outputs of LLM activities, such as either maps or estimates.<br>d) there should be focus upon development of integration methods that can be used operationally, in particular with respect to field surveys<br>e) goal-orientated integration solutions should be emphasised<br>f) there should be clear statistically worked through demonstrations of the PFII methods<br>g) PFII should be built into related work with a functional and process domain focus, such as grossing-up from local processes to regional processes<br>h) PFII should be undertaken within a context of using the results as indicators |
| **(iii) Sample Infomation Form & Use** | **(iv) Census Infomation Form & Use** |
| a) the object basis for PFII needs to be examined – are our FS and RS derived objects really comparable ?<br>b) tools are needed for integration of the nomenclatures of partial and full coverage information.<br>c) the strategic locating of samples needs to be examined, particularly if this is based upon images<br>d) goal-orientated sampling should be investigated further<br>e) the statistical procedures relating to sample data should be reviewed | a) the object basis for PFII needs to be examined – are our FS and RS derived objects really comparable ?<br>b) tools are needed for integration of the nomenclatures of partial and full coverage information<br>c) supplementary full coverage information layers, such as agricultural statistics data, should be investigated<br>d) there should be focus on the spatial distribution / context setting of aggreements & disagreements between sample and census layers and other data<br>e) domain-based thinking, such as with respect to spectral -vs- functional domains should be investigated |

In terms of the wider, applied framework of PFII the points raised divide between two clear issues:
- on the one hand the need to develop PFII ideas in order to fill in gaps in current LLM activities or to more fully exploit current LLM structures
- on the other hand the need to develop and implement PFII in step with developments in the needs of various user communities for the types of outputs it might generate and the translation of outputs into environmental and ecological indicators.

Three levels can be seen in the points noted concerning the methodological framework for PFII:
- there is the need for a clear typology of integration methods, including their relationhips to different types of outputs, operational use and statistical aspects.
- the underlying assumptions of PFII methods regarding scaling issues and natural phenomena need to be examined
- the methodologies for PFII should be developed in the context of the applied framework, such as in terms of goal-orientated solutions and the use of outputs as indicators.

Issues that had been noted previously, such as a goal-orientated approach and the review of statistical procedures, were also noted with respect to the needs of the partial coverage information. Concerns for fundamental aspects of sampling such as sampling location were also noted.
With respect to the needs and use of full coverage information it was clear that there are still several largely unexplored possibilities; each of the three that were noted represents a considerable developmental and experimental task.
At the level of the census and sample information that might be used in PFII, two common issues were noted : the need to ask if the census and sample data relate to comparable objects and the need to develop nomenclatures for their integration.

## 6. Further Nordic and NordLaM activity possibilities under the PFII theme

Two tasks were identified for developing the PFII theme, along the lines of the points raised in the presentations and discussions.

1. CB: A comparison of a pair of operational LLM activities with integration of partial and full coverage information, with reference to the typology of integration methods described by MK. This could comprise a comparison of the approaches used in the Austrian work described by TW and the CS in GB.
2. BB/GS: A demonstration of the possibilities for integration based on stratification at a trans-national level, with examples of outputs related to speciific policy issues, such as scrub clearance. The stratification could be based upon 2 layers such as the ‘European environmental classification’ and a Europe-wide land cover map.

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