Area frame survey of land resources

AR18×18 system description

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Cover photo: Land resources waiting to be uncovered, Raudfjellet, Hedmark.
Photo: Geir-Harald Strand, © NIJOS

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Sammendrag (Norwegian):

AR18×18 er en utvalgsundersøkelse av Norges arealressurser. Metoden som benyttes i undersøkelsen er knyttet til Eurostat's *Lucas* statistikk, men er tilpasset norske forhold og behov. Data som i Norge kan hentes fra offentlige registre eller andre tilgjengelige kilder med god kvalitet blir ikke samlet inn. Samtidig er undersøkelsen utvidet med en kartlegging av vegetasjon og arealdekke på utvalgsflatene. Hensikten med undersøkelsen er å etablere en forventningsrett og presis, heldekkende norsk arealstatistikk. Systemet vil også gi grunnlag for et fremtidig arealregnskap som beskriver endringer i arealressursene.

Abstract (English):

AR18×18 is an area frame survey of land resources in Norway, methodologically linked to the *Lucas* survey carried out by Eurostat. The method has been adapted to Norwegian conditions. Data accessible through existing mapping systems and public registers are not collected. On the other hand, the survey is strengthened with a land cover mapping component. The purpose of the survey is to establish an unbiased and accurate land cover and land use statistic providing a description of the state of land resources in Norway. The study will also provide a baseline for future reports regarding changes in land resources.

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Preface

It is the responsibility of the Norwegian institute of land inventory (NIJOS) to compile land resources statistics for Norway. This has traditionally been done through a number of loosely coupled survey and mapping programs. These programs include the national forest inventory (using a point sample), the mapping of land types below the tree line (using traditional all-exhaustive mapping at scale 1:5,000) and various systems for land resource mapping above the tree line. All of these programs have thematic and spatial limitations and none of them have a true national coverage.

The recent increase in public interest in, and growing conflicts over, land resources has created a demand for an integrated land resource accounting system with a full national coverage. With AR18×18, NIJOS intends to meet this demand. The system is both robust and flexible and has the capability to include a range of topics related to the land resources.

AR18×18 started as a pilot project in the mountains of Hedmark County in 2004. Further testing was carried out during the 2005 field season. The system developed through these tests is described in this report, along with a summary of the experience with - and assessment of - the method.

NIJOS intends to carry out the AR18×18 survey on a national scale during the next few years. Progress will depend on available resources and no definite date has been set for the completion of the survey.

Ås, February 22nd 2006

Nils Karbø
/Director general/

Executive summary

AR18×18 is an area frame survey of land resources in Norway, methodologically linked to the *Lucas* survey carried out by Eurostat (Eurostat 2003). The purpose of the survey is to establish an unbiased and accurate land cover and land use statistic providing a description of the state of land resources in Norway. The study will also provide a baseline for future reports regarding changes in land resources – a national land resource accounting system.

AR18×18 is based on *Lucas* (Land use/cover agricultural survey), a European area frame survey carried out in the EU countries by Eurostat. The sampling units of *Lucas* are points located on the intersections of an 18 × 18 kilometer grid mesh throughout Europe. Each of these points is the centre of a Primary Statistical Unit (PSU) of 1500 × 600 meters. The *Lucas* survey is carried out on ten sample points scattered within each PSU. The Norwegian modification of *Lucas* is to add a land cover survey of the whole PSU following NIJOS' system for vegetation and land cover mapping at intermediate scale (1:20,000).

Operational experience with the AR18×18 method was gained during the first pilot phase in 2004 and 2005. These experiences have led to adjustments improving the method and also provided the basis for a preliminary evaluation of the method. The overall assessment is that the *Lucas* survey methodology works well, while the *Lucas* measurements have shortcomings regarding the definitions and detailed instructions for how measurements should be carried out. This is in particular the case for *land use* measurements, landscape *photography,* natural *hazards* and registration of *linear features* along transects. In AR18×18, the system is improved by adding land cover mapping of the entire PSU. This is a necessary adjustment in order to create a practical and functional survey addressing the needs for land resource statistics in Norway.

The AR18×18 sampling method, based on *Lucas,* is statistically sound and efficient. The systematic sample strategy ensures that the sample is spread out as much as possible, thus creating a representative replica of the population and covering maximum variability. The simplicity of the method also leads to high flexibility. Statistics can easily be prepared for any regional subset of the data. It is observed that the AR18×18 easily can be extended to by densification (e.g. using a 9×9 kilometer grid). This will improve the precision of the estimates and is in particular useful when the goal is to provide statistics for smaller regions.

Land use and land cover types that cover very small areas will not be recorded by the land cover mapping method used in AR18×18. This is a question of detectability and the problem is related to the method of measurement, although some times falsely attributed to the sampling method. The challenge is to design appropriate observation methods to cover these features while keeping the workload of the field crew at an acceptable level and within a realistic budget. Uncommon or even rare phenomena will also be detected and recorded as long as the occurrence is spatially random. Problems arise when the spatial distribution of rare features is autocorrelated.

In situ assessment is an essential part of the AR18×18 methodology. Reliable land use and land cover assessments outside the built-up and agricultural land is not possible from aerial photo interpretation alone. NIJOS intends to carry out the AR18×18 survey on a national scale during the next few years. Progress will depend on available resources and no definite date has been set for the completion of the survey.

Content

Background

The only feasible approach to survey land resources on a national scale – including mountain areas - in Norway is to use statistical sampling. An ordinary survey is simply too expensive. The area extent of the conterminous Norway is approximately 324,000 km^2. A complete land cover survey will cost more than NOK 1 billion, even when the amount of details is kept at a moderate level. A realistic budget for a highly detailed survey is even higher, around NOK 5 billion. A statistical area frame survey, on the other hand, can be carried out on a budget around NOK 8-10 million. The sampling based survey can also be repeated at fixed intervals in order to provide information about changes in land resources.

AR18×18 is an area frame survey of land resources in Norway, methodologically linked to the *Lucas* survey carried out by Eurostat (Eurostat 2003). The purpose of AR18×18 is to establish an unbiased and fairly accurate land cover and land use statistic providing a description of the state of land resources in Norway. The study will also provide a baseline for future surveillance of changes in land resources.

AR18×18 is implemented by the Norwegian institute of land inventory (NIJOS). Statistics Norway (SSB) has participated in the development of the approach and the adaptation of the *Lucas* methodology to Norwegian conditions and needs.

The method was first tested in the mountains of Hedmark County, in a field survey carried out during the summer season of 2004 (Rekdal and Strand 2005, Strand and Rekdal 2005). The field survey was extended to full coverage of five counties in 2005. The mountain areas of another three counties were also surveyed. Total coverage by the end of 2005 is approximately 20% of Norway (Figure 1).

Figure 1: Location of the 209 sample plots surveyed during the 2004 and 2005 pilot phase.

Objectives

The importance of land resources and the need for land resource surveys are internationally recognized (Young 2000). The objective of AR18×18 is to provide a homogeneous, unbiased and accurate land cover and land use statistic for Norway. Current statistics is limited to nine categories and patched together from several sources, mostly with incomplete coverage (eg NOU 2001:7). AR18×18 will provide a consistent national overview with known statistical properties. The results of the survey will also act as a baseline for future surveillance of changes in land resources at the national scale. Particular needs of high national importance include

- A consistent and complete land use and land cover statistic for Norway.
- A baseline for future surveillance accounting for change in land use and land cover
- A national index of sustainable management of land resources involving measurement of "irreversible reduction of biologically productive areas" (NOU 2005:5)
- Background for policy development in agriculture, forestry, environment and physical planning
- Reference material for evaluation of the achievement of national goals regarding the management of land resources

Additional needs and uses that have been identified are:

- Information on the overall distribution of land resources in order to provide a background for identification of hot-spots (Areas where resources of high agricultural or environmental value should be surveyed in greater detail).
- Background data for assessment of the environmental impact of emissions from the Norwegian oil industry in order to prioritize areas where reduction of emissions will have the largest positive impact on the environment
- National and regional assessments of the potential for outfield pasture to support husbandry and domesticated reindeer.
- GAP analysis (Scott et al. 1993, Jennings 2000) comparing the composition of land in protected areas to national land statistics.
- A framework for a national landscape survey, complementing the current landscape monitoring system for agricultural landscapes
- A framework for a national statistical survey of soils
- Frameworks for national statistical surveys of birds, plants, habitats and immobile cultural heritage objects.
- Studies, scenarios and monitoring related to climate change
- Source material for calibration and validation in satellite remote sensing of land resources
- Supplement and support to the *Corine* approach to land cover mapping at the European level

History

The need for national land resource statistics in Norway was expressed in NOU 1972:44 and the first decision to establish a land resource accounting system for Norway came in the late 1970's following recommendations given in NOU 1977:33. Implementation was carried out by SSB with assistance from the Norwegian mapping authority and a number of other national and local authorities. Existing data sources were explored (Einevoll 1976, Lydersen and Nilsen 1977) but the overall method was an area frame survey of point locations, based on maps and aerial photo interpretation. Fieldwork was rarely employed. The methodology is accounted for by Sæbø and Engebretsen (1979), Sæbø (1983) and Engebretsen (1986). The first results were published in 1981 (SSB 1981). The project did continue on a smaller scale into the 1980's, mainly trying to use satellite images, but the was formally closed down in 1988.

Land resources were generally absent from the political agenda in Norway throughout the late 1980's and during the 1990's, but have been given increased attention again over the last ten years (Schøning 1993, Dysterud et al. 1996, NOU 2001:35, NOU 2002:9, St meld 17 (1998-1999), St meld 19 (1999-2000), NOU 2004:28). A growing national economy has created new uses for land resources. Various interest groups, including environmentalists, hikers, tourist industry, developers, pastoralists, farmers and foresters are now taking an interest in the management, resulting in conflicts over the use and protection of land resources. National authorities, policy makers and the interested public in general all demand better information about the situation and possible scenarios for future land use (NOU 2001:2).

Some of the needs for information about land resources can be met using data from existing surveys, including the detailed land typology maps, the national forest inventory, the national monitoring of agricultural landscapes and the agricultural soil maps. But none of these sources have a complete national coverage, and some also lack a time stamp (i.e they are created over many years and the date of the information from different locations can vary substantially). There is thus a need for a comprehensive, integrated land resource survey and a land resource accounting system in Norway.

Alternative approaches have been considered. Corine Land Cover (de Lima 2005) is now being implemented in Norway by NIJOS. The system is tailored to provide cartographic information on a continental level. It uses a generalization methodology that inevitably leads to biased statistical results (Strand 1997) and is not suitable for production of statistics and accounting systems on the national and sub-national level. Various methods based on satellite remote sensing have also been tested in Norway over the last 30 years. The experience is generally that the Norwegian topography represents an extraordinary challenge, that the results are highly uncertain and that auxiliary data is needed (eg. Ødegaard and Sickel 2005).

NIJOS first suggested a national area frame survey of land resources in 2000 (Strand 2002). The idea did, however, not materialize and was left dormant until 2003 when Statistics Norway (SSB) approached NIJOS with the intention to investigate whether the *Lucas* area frame survey (described below) carried out by Eurostat could be implemented in Norway. The deliberations soon led to the development of an operational methodology (AR18×18) and a pilot implementation in the mountains of Hedmark County during the summer of 2004. Further adjustments and pilot surveys were carried out in 2005, initiating implementation on a national scale.

NIJOS intends to implement the AR18×18 survey on a national scale during the next few years. Progress will depend on available resources and no definite date has been set for the completion of the survey.

Survey method

AR18×18 is based on *Lucas* (Land use/cover agricultural survey), a European area frame survey carried out in the EU countries by Eurostat (Eurostat 2003). The sampling units of *Lucas* are points located on the intersections of an 18 × 18 kilometer grid mesh throughout Europe. Each of these points is the centre of a Primary Statistical Unit (PSU) of 1500 × 600 meters. Ten additional points, known as Secondary Statistical Units (SSU), are located inside each PSU (Figure 2). Measurements in *Lucas* are mostly made on an approximately 7 m^2 plot around each SSU and on a transect through the five northernmost SSUs of each PSU.

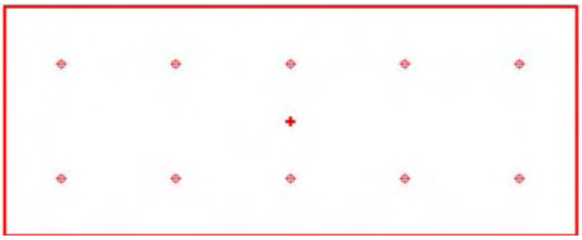

Figure 2: A Lucas sampling site consists of a Primary Statistical Unit (PSU) shaped as a 1500 × 600 meter rectangle. Ten Secondary Statistical Unites (SSU) are located inside the PSU. The distance between the SSU's is 300 meter.

AR18×18 is using the Lucas concept of PSU and SSU locations. The major modification is that AR18×18 also collects land cover data for the rectangular PSU covering 1500 × 600 meter (0.9 km^2). The PSU provides a better coverage of the area in the data collection and improves the probability for inclusion of rare features. It also allows the survey to be treated as a single stage systematic sample instead of a two-stage sample.

A PSU is included in the survey as long as any part of it falls within Norwegian land areas (including freshwater). The estimated total number of sampling sites in the survey is 1083, but the actual number may change slightly as PSUs along the complex coastline of western- and northern Norway remains to be studied in detail.

Survey locations

A field map of each survey site is prepared using topographical maps provided by the Norwegian Mapping Authority (Statens kartverk). The map (Figure 3) consists of a detailed image of the PSU and its immediate surroundings (based on topographical map in scale 1:50,000) and an access map (based on topographical map in scale 1:250,000). Key information including the site identification, name of the municipality and the coordinates of the center point is also included.

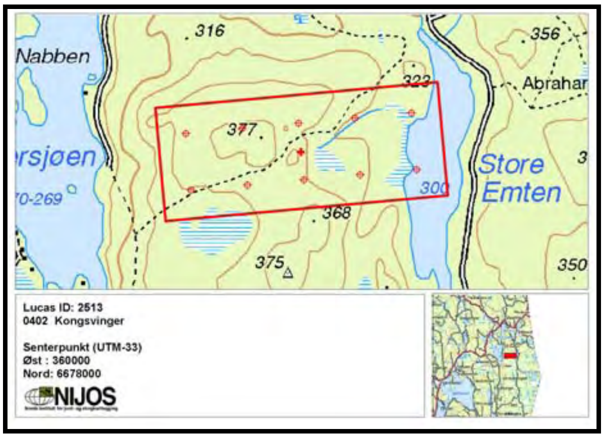

Figure 3: Field map provided for an AR18×18 sampling site. [Base map: N50 Rasterdata, Statens kartver. Permit MAD 12003-R125241]

Coordinates for all PSUs and SSUs in the survey has been generated and entered into computer files. The coordinates are uploaded from these files into handheld GPS receivers used by the crew to locate the SSUs in the field.

GPS equipped with external antenna is used in forest areas where reception is known to be difficult. Detailed instructions for approach to the SSUs are provided in the survey guidelines. These guidelines also regulate behavior in cases where GPS reception is failing. Special attention is given to the fact that Norwegian mountain terrain may lead to significant deterioration of GPS signals due to echo effects.

Land cover survey

The land cover survey of the PSUs is carried out following NIJOS' system for vegetation and land cover mapping at intermediate scale (1:20,000). The system is developed through mapping projects throughout Norway over a period of 25 years (Rekdal and Larsson 2005). The system is thoroughly tested, the cost is acceptable and the results are used for quantification and assessment of many aspects of land resources.

Figure 4: Yngve Rekdal shown drawing a land cover map on a stereo pair of aerial photographs during field work in 2005. Photo: Geir-H Strand © NIJOS.

The basic nomenclature of NIJOS' system for vegetation and land cover mapping consists of 54 land types (45 of these are vegetation types). A number of additional registrations are added to these basic observations. Examples are rock outcrops, coverage percentage of lichen, willow or fern and areas with particularly rich grass cover. There is close coherence between this mapping system and a classification system often used for detailed vegetation descriptions in Norway (Fremstad 1997). The differences are mainly that the NIJOS-approach is less detailed for vegetation types that cover small areas or require highly specialized botanical knowledge for identification. The hierarchical sequence of key registrations in the two systems is also somewhat different because the NIJOS system is aiming to be efficient during applied mapping in the field.

Vegetation and land cover mapping following the NIJOS system is carried out in the field using aerial photographs usually at scale 1:40 000 (Figure 4). Both black and white and IR photos can be used, but IR photos are preferred if available. Vegetation polygons are drawn directly on the photos (Figure 5) and later digitized and processed using GIS software.

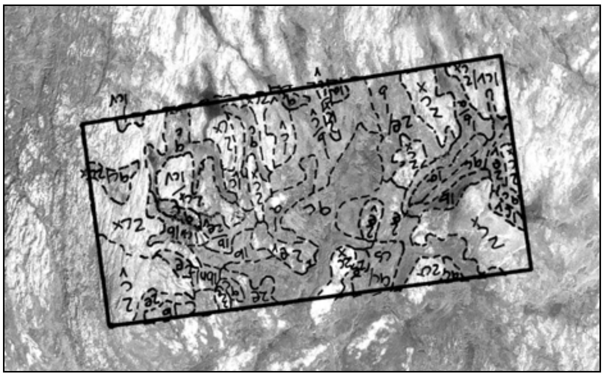

Figure 5: Aerial photograph with land cover interpretation (Site 2028, Kvikne, Tynset)

The minimum polygon size is 0,1 haa, but a mosaic of two different vegetation types can be registered for a polygon when each type covers at least 25% of the area. The dominant vegetation type is for statistical purposes counted as covering on average 62,5% of each polygon, while the secondary vegetation type is counted for the remaining 37,5%. A simplified vegetation map based on the measurements from Figure 5 is shown in Figure 6 below.

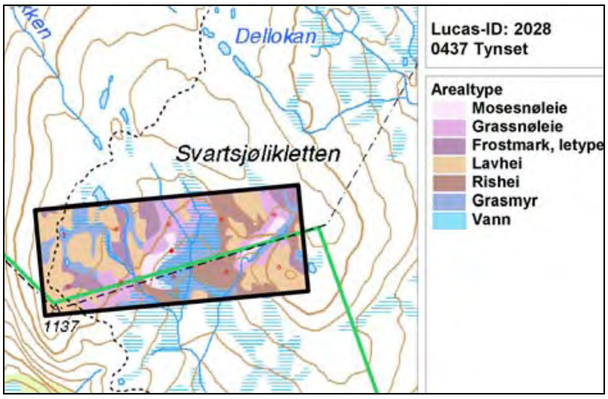

Figure 6: Simplified land cover map (Site 2028, Kvikne, Tynset). [Base map: N50 Rasterdata, Statens kartver. Permit MAD 12003-R125241]

Lucas measurements

The field measurements consist of

- A subset of the *Lucas* field form
- Photographs taken at one SSU according to *Lucas* instructions
- Registrations of the landscape features

The subset of the *Lucas* field form has excluded those parts of the form that

- can be obtained from official statistics or public registers
- are considered irrelevant in Norway due to local conditions
- according to experienced field personnel are impossible to measure with acceptable precision

The *Lucas* farmer interview is not included in Norway because better data on the same topics can be obtained from the Census of Agricultur and Forestry carried out by Statistics Norway (Steinset 2006).

Detailed vegetation class

The vegetation class according to the detailed system used in Norway (Fremstad 1997) is measured at the SSUs. These registrations will provide a source for a statistic concerning vegetation at the most detailed level.

Landscape parameters

A number of landscape parameters are also obtained at the PSUs. These include indicators concerning

- Buildings
- Agricultural activities
- Pasturage
- Transhumance

These data are measured on a binary scale (presence-absence).

The landscape parameters will be used as a supplement to the national survey of agricultural landscapes, using AR18×18 to extend this survey to the overall national landscape.

Data analysis

Each survey location represents an area covering 18 × 18 kilometers (324 km^2). Since the size of a PSU is 1500 × 600 meter (0,9 km^2), observations made in the survey of the PSU generally carry a weight of 324/0,9 = 360 (Figure 7).

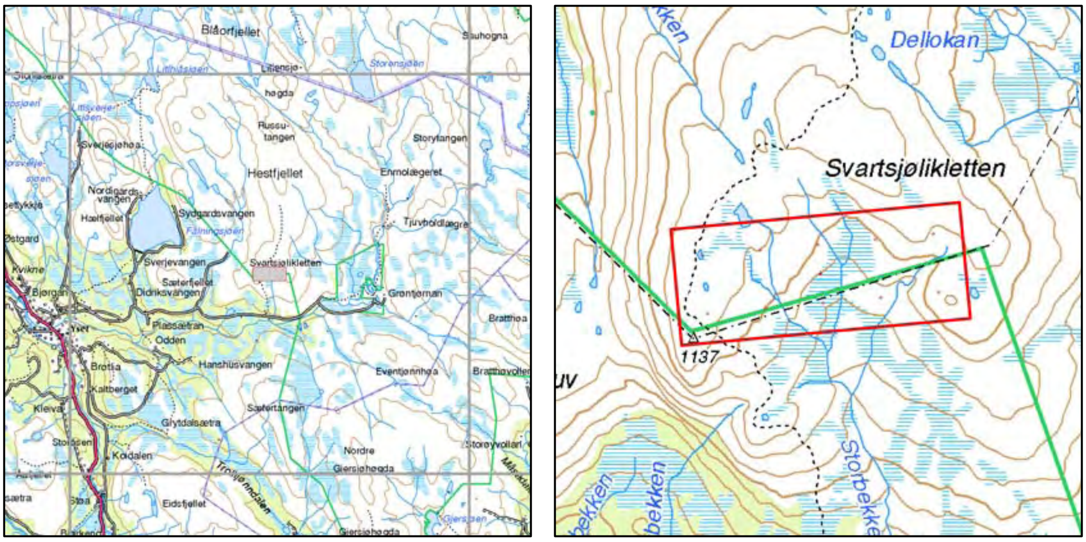

Figure 7: (a) A sample site in AR18×18 represents an area of 324 km^2 (18 × 18 kilometer) (b) The Primary Statistical Unit (PSU) cover an area of 1500 × 600 meter (0,9 km^2). PSU's are defined in projection UTM-33 and appear rotated on maps in other projections (here in UTM-32). [Base map: N250 and N50 Rasterdata, Statens kartver. Permit MAD 12003-R125241]

The results from the survey are presented in reports as tabular statistics and maps. Examples of the content of these reports are shown in the figures and tables below.

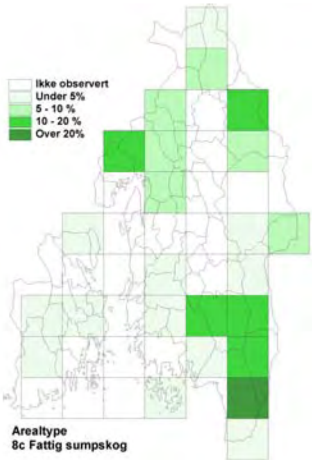

Figure 8: Map showing the distribution of land cover class 8c “Poor swamp forest” in four counties surrounding the Oslo fiord (south-eastern Norway) based on land cover maps of the PSUs.

The map showing the distribution of a observed land cover type (Figure 8) is made according to the presentation usually found in Lucas reports. This particular example concentrates on the area surrounding the Oslo fiord, an area too small to show any interesting regional patterns. As more data is collected, such maps will be presented for large regions or the whole country. These maps will provide a useful overview of the spatial structure of the distribution of land cover types. Such maps can be used to identify regional hot spots and illustrate regional trends or patterns.

Land cover	Mountain area Hedmark		Elevation (meters)		
	Km²	%	Min	Max	Mean
1a Moss snow bed	27	0,4	1 070	1 250	1 133
1b Sedge and grass snow bed	85	1,3	940	1 260	1 119
1c Polygon stone land	217	3,3	1 035	1 270	1 104
2b Dry grass heath	98	1,5	1 036	1 273	1 098
2c Lichen heath	2 287	35,3	820	1 500	1 071
2d Mountain avens heath	27	0,4	940	1 040	993
2e Dwarf shrup heath	1 905	29,4	860	1 280	1 053
2f Alpine heather heath	438	6,8	760	1 073	846
3a Low herb meadow	36	0,6	920	1 280	1 076
3b Tall forb meadow	126	2,0	808	1 213	1 065
9a Bog	122	1,9	759	1 030	839
9c Fen	702	10,8	814	1 280	1 016
9e Sedge marsh	8	0,1	760	992	903
12b Boulder field	287	4,4	800	1 640	1415
12h Water	115	1,8			
TOTAL	**6 480**	**100**			

Table 1: Statistical summary of the land cover in the mountain areas of Hedmark County (eastern Norway) based on land cover maps of the PSUs (from Rekdal and Strand 2005).

A typical statistical summary is shown in Table 1 (above) and Figure 9 (below). These particular cases are summaries of the land cover classes found in the mountains of Hedmark County (eastern Norway) based on data from the pilot survey carried out in 2004. Figures show coverage (in km^2 and %) and the elevation range where each land cover class is found.

Statistical summaries can be made for every parameter measured by the survey. This includes, in addition to the land cover classes, a more detailed vegetation classification, a subset of the Lucas parameters and a number of parameters characterizing the landscape. Furthermore, these statistical summaries can also be made for other regional subdivisions than the administrative units. Some candidates for statistical summaries are

- The agricultural landscape
- Areas where grazing is suspected to exceed the carrying capacity
- Protected areas
- The coastal zone
- Built-up areas (according to the definition given by Statistics Norway)
- The mountains
- Landscape regions
- Undisturbed areas (according to definition given by Environmental Authorities)
- Corine Land Cover classes

The categories used in the land cover survey can also be converted to other classifications systems. An example is the EUNIS habitat classification (Davies et.al 2004). This provides opportunities to use the data collected through *AR18×18* as a basis for descriptions of Norwegian land resources for a number of different purposes, including national reports to international agencies and processes.

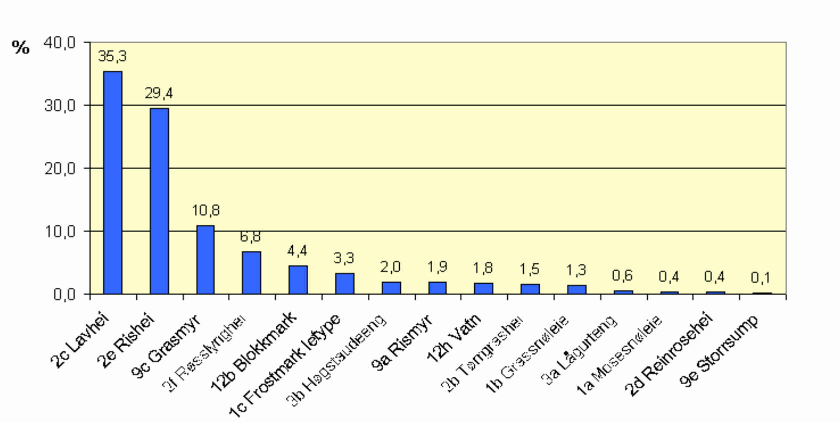

Figure 9: Graphical representation of the land cover classes in the mountain areas of Hedmark County (eastern Norway) based on land cover maps of the PSUs (from Rekdal and Strand 2005).

Statistical summaries and maps can also be made for results calculated from the original observations. Land cover can be translated into grazing capacity for various animals, both wild and domestic. Other derivatives are indexes for biodiversity and sustainability. Analysis of the spatial structure of the land cover maps can be used in landscape analysis. The system will constitute a highly flexible basis for reports and statistics concerning the status and development of the land resources in Norway.

Statistical considerations

The area frame survey is a systematic random sample. The systematic element is that a location is surveyed for every 18 kilometer along the grid mesh. The random element is that the starting point of the grid is located randomly. This sampling strategy is in reality a *cluster sample* consisting of a single cluster, but where every element of this cluster is included in the sample.

It is possible to construct 360 different systematic samples based on the chosen survey strategy: Each of the survey locations is 0,9 km^2 (1500×600 meters), the locations are interspaced with 18 kilometers in both directions and $18^2/0{,}9 = 360$. The sampling frame thus consists of 360 clusters, each containing a national coverage of equally interspaced sampling locations. By choosing a random starting location, one of these clusters is selected and all the locations in that particular cluster is included in the survey.

The systematic random sample is particularly efficient for geographical surveys because it avoids selection of elements located close together (Thompson 2002). Geographical phenomena, including land resources and related features, are usually autocorrelated. Autocorrelation is the effect that places located close to each other tend to be more similar than places located further away from each other. The systematic sampling strategy ensures that the variance in the cluster is as high as possible while the variance between the clusters is as small as possible. This implies that the likelihood that the sample represents the full variability of the population is maximized.

To profit from this strategy, it is important to include all the elements of the cluster in the sample. The practical implication is that every location that includes part of the population should be included in the sample. Field mapping units partly located in Sweden or including a substantial area of ocean are all included when they also contain part of the Norwegian land area although only the part falling inside Norway is actually mapped. The rule also applies when the area frame survey is used to estimate land resources for smaller regions. Every field mapping unit containing a part of the said region should be included in the sample.

Estimation

The calculations based on the systematic sample are straightforward as long as the preconditions above are observed. An unbiased estimator of the total of any parameter *x* for a region is

$$\hat{\tau} = 360 \times \sum_i^m x_i$$

where *m* is the number of locations in the sample and x_i is the measurement of *x* for that part of location *i* that belongs to said region. A pragmatic adjustment can be made when the total area *A* of the study region is known, by including the measurement of a_i the size of the area of each location that belongs to the study region

$$\hat{\tau} = \frac{A \times \sum_i^m x_i}{\sum_i^m a_i}$$

where $A / \sum a_i$ will be approximately 360.

Variance

The systematic sample is a sample with only one element, since it is the cluster – and not the locations – that is being sampled. It is thus not possible to calculate an unbiased estimate of the variance and standard error based on the sample. The within-cluster variance can, however, be calculated. This provides a biased, usually too high and thus conservative estimate of the sampling variance (Thompson 2002). The simple variance estimate is

$$Var(\hat{\tau}) = N(N-n)\frac{s_x^2}{n}$$

which allows a conservative estimate of the confidence interval of the projected totals.

Assessment

Extensive experience with the AR18×18 method has been gained during the pilot phase in 2004 and 2005. These experiences have led to adjustments improving the method and also provided the basis for a preliminary assessment of the method.

The Lucas survey

AR18×18 is using the *Lucas* survey methodology and includes a subset of the *Lucas* measurements. The overall assessment is that the *Lucas* survey methodology works well, while the *Lucas* measurements have shortcomings regarding the definitions and detailed instructions for how measurements should be carried out. This is in particular the case for *land use* measurements, landscape *photography,* natural *hazards* and registration of *linear features* along transects between the SSUs. The categories defined by Lucas are not mutually exclusive and definitions are often too vague, leaving their interpretation to the field crew. Landscape photography can provide powerful documentation, but NIJOS' experience from using this method over many years is that it requires far more precise instructions and documentation than included in *Lucas*. The parameters developed specially for the Norwegian survey are thus expected to provide better and more reliable information than the parameters adopted from the *Lucas* manual. The two-stage approach is a complicating factor as long as the first stage is a systematic sample with size *n=1*.

Sampling method

The AR18×18 method is statistically sound and efficient. The systematic sample strategy ensures that the sample is spread out as much as possible, thus creating a representative replica of the population and covering maximum variability.

The simplicity of the method also leads to high flexibility. Statistics can easily be prepared for any regional subset of the data. Examples are administrative units (e.g. counties), topographic units (e.g. mountains) and thematic units (e.g. protected areas). It is, however, strongly recommended that all the PSUs overlapping with the regional subset is included when the system is used for such purpose. Two-stage sampling (e.g. including only those PSUs where the center is located in the region) as was done in the first pilot survey in the mountains of Hedmark does weaken the statistics considerably because the second sampling stage involves sampling proportional to size (PPS).

It is observed that the AR18×18 easily can be extended to by densification (e.g. using a 9×9 kilometer grid). This will improve the precision of the estimates, and is in particular useful when the framework is used to provide statistics for smaller regions. Such a study is under consideration for the Setesdalsheiene landscape in southern Norway where concerns regarding the sustainability of the current use of mountain pasture as led to a demand for better land resource statistics. The region is too small for AR18×18 to provide sufficiently accurate results, but too large for a detailed inventory. A local densification of AR18×18 to AR9×9 may provide an acceptable solution.

The systematic sampling method employed in AR18×18 does not allow calculation of unbiased variance estimates. Variance can be calculated assuming that the PSUs constitute a simple random sample. This is usually a conservative estimate, since the estimate tend to be too high. Methods for improved calculations of the true sample variance do exist (e.g. Murthy and Rao 1988) and should be tested.

Detectability

Land use and land cover types that cover very small areas will not be picked up by the land cover mapping method used in AR18×18. This is a question of detectability and the problem is related to the method of measurement, although some times falsely attributed to the sampling method. Spring vegetation and tiny farm ponds are two examples of features usually covering too small area to be included in the maps according to the chosen mapping method. These features can still be measured, either cartographically as points or by measuring them as an attribute of the PSU itself (using a form to register presence or absence). Detectability is also the real issue when topics of a highly esoteric nature require specially trained observers. Examples are the existence of certain moss and lichens considered important in an environmental context. The challenge is to design appropriate observation methods to cover these features while keeping the workload of the field crew at an acceptable level and within a realistic budget.

Land use and related phenomena may also have a rather elusive spatial presence and be difficult to map, even in the field. Examples are impact of pasture or transhumance. Again, using a form to register presence or absence is a possible solution. This does, however, require objective criteria for determination of the presence/absence of these phenomena, even when the absolute delineation of the land used is impossible.

Uncommon and rare phenomena

The simple area frame survey using a systematic sample is also suitable for detecting uncommon or even rare phenomena as long as the occurrence is spatially random. Problems arise when the spatial distribution of rare features is autocorrelated. A rare and highly autocorrelated phenomena will usually not be detected by the survey but are easily overestimated when and if it is found. The solution is to increase the sampling intensity in order to increase the probability of detecting the phenomena in the first place and then the employ *adaptive sampling* (Thompson 2002) as an extension of the systematic sample in the areas where the rare phenomena is found.

Field work

Fieldwork is an essential part of the AR18×18 methodology. It is not possible to make reliable land use and land cover assessments outside the built-up and agricultural land from remote aerial photo interpretation alone.

Fieldwork is efficient but requires good planning. The system involves a considerable amount of field logistics. These start with the preparation of field maps and aerial photographs. Appropriate travel routes must be planned in advance in order to develop efficient schedules and minimize costs. NIJOS furthermore attempts to combine the fieldwork for several surveys, bringing the qualifications of individual field workers into the consideration. These challenges will increase as the survey moves into wilder and more remote areas in western and northern Norway.

Fieldwork also raises the issue of crew safety. NIJOS does have comprehensive systems to ensure the safety of field crews. The locations of all PSUs are deposited at a security company and field crew routinely inform the agency at the start and end of the trek to and from each PSU, setting off an alarm if they don't return within a given time period. For more remote areas, the crew will be ordered to work in teams of two. Particularly difficult locations will either be assessed from a distance (using a telescope) or even interpreted from aerial photographs when access is considered dangerous.

Alternative methods

The two foremost alternatives to area frame sampling are Corine Land Cover (CLC) and satellite remote sensing. Corine Land Cover (de Lima 2005) is now under implementation in Norway. This project is also carried out by NIJOS. CLC is adapted to provide cartographic information on the continental European level. The system uses a generalization methodology that implies biased statistical results (Strand 1997) and is not suitable for production of statistics and accounting systems on the national and sub-national level. The AR18×18 area frame survey is a necessary addition to the CLC process. The area frame survey provides a basis for interpretation and adjustment of the CLC statistic by documenting the variability within the CLC categories. It is also our understanding that growing attention is given to the need to strengthen the CLC methodology by adding an *in situ* monitoring component by the European Environmental Agency (EEA) who is the owner of the CLC process.

Various methods based on satellite remote sensing have been tested in Norway over the last 30 years. The experience is generally that the Norwegian topography represents an extraordinary challenge. Accuracy is rarely evaluated, but often found to be poor when examined. Auxiliary data is also needed in order to improve the results from remote sensing techniques. In this perspective, satellite remote sensing is not an alternative to *in situ* monitoring. The situation is rather that *in situ* monitoring is a prerequisite for further development of satellite remote sensing technology.

AR18×18 will have a potential to contribute in several ways to the development of remote sensing systems in Norway. The data collected *in situ* will provide the analysts who carry out manual interpretation of satellite images with information needed to understand and recognize the image features. Maps and photos of the PSUs will give the analyst extraordinary insight into the actual conditions on the ground in far more areas than usually available through field visits by the individual analyst. For unsupervised classification, *in situ* data is needed as a firm basis for the post classification labeling of the categories. In supervised classification, *in situ* data is needed for "training" and calibration of the models. And for all remote sensing projects, using *in situ* data collected in a non-purposive manner and utilized independent of the whole calibration, training and labeling procedure is the only way to produce a trustworthy accuracy assessment of the results.

Potential

The main purpose of AR18×18 is to provide national land cover and land use statistics and thus create the basis for a land resource accounting system. But AR18×18 can also be used as a framework fulfilling other functions. NIJOS has since 1998 carried out a national surveillance of agricultural landscapes, known as the 3Q program (Dramstad et al. 2002). AR18×18 will be used to extend this surveillance to the national landscape at large. The Directorate for Nature Management (DN) intends to use the same framework for a national bird survey. NIJOS has also developed a practical method for cultural heritage surveys in the outfields (Stensgaard and Strand 2005) and Hedmark University College has started a project using the AR18×18 framework where this method is being tested and further developed as a tool to create regional and national cultural heritage statistics.

Status

Approximately 20% of the locations have been surveyed in the field by the end of 2005. The material includes all mountain areas in southeastern Norway and a complete coverage of six (out of 19) counties. Reports based on the existing data will be prepared in 2006.

NIJOS intends to carry out the AR18×18 survey on a national scale during the next few years. Progress will depend on available resources and no definite date has been set for the completion of the survey.

References

Davies, C.E, Moss, D. and Hill, M.O. 2004 *EUNIS Habitat Classification Revised 2004.* Report to European Environmental Agency. European Topic Centre on Nature protection and Biodiversity. October 2004.

Dramstad, W. E., Fjellstad, W. J., Strand, G.-H., Mathiesen, H. F., Engan, G. & Stokland, J. N. 2002. Development and implementation of the Norwegian monitoring programme for agricultural landscapes, *Journal of Environmental Management*, **64:** 49 – 63

Dysterud, M.V., Rogstad, L. and Schøning, P. (eds). 1996. Bærekraftig arealpolitikk og behovet for arealstatistikk, Notater fra Statistisk sentralbyrå, 96/42, Oslo 1996

Einevoll, O. 1976. Jordregisteret som arealrekneskap, Unpublished memo, Jordregisterinstituttet, 31 pp., Ås 1977

Engebretsen, Ø. 1986. Punktsampling som grunnlag for regional arealbudsjettering, *Rapporter fra Statistisk sentralbyrå*, **86/8**, Oslo 1986

Eurostat, 2003. *The Lucas survey. European statisticians monitor territory*. Office for Official Publications of the European Communities, Luxembourg 2003

Fremstad, E. 1997. Vegetasjonstyper i Norge. *NINA Temahefte:* **12**, Trondheim 1997

Jennings, M.D. 2000. GAP analysis: Concepts, methods and recent results. *Landscape Ecology*, **15**: 5 – 20

De Lima, M.V.N. 2005. Image2000 and CLC2000. Products and Methods. Corine Land Cover updating for the year 2000, Joint Research Centre, **EUR 21757 EN**, Ispra 2005

Lydersen, S. and Nilsen, E. 1977. Arealregnskap og jordregister : Arealopplysningene i jordregistrer vurdert i lys av databehovet for et arealregnskap. *NIBR Arbeidsrapport* **8/77**, Oslo 1977

Murthy, M.N. and Rao, T.J. 1988. Systematic sampling with illustrative examples. In P.R.Krishnaiah and C.R.Rao (eds.) *Handbook of statistics, Vol 6, Sampling*. pp. 147 - 185, Elsevier, Amsterdam

NOU 1972:44. Om statistikkbehovet i regional planlegging. *Norges offentlige utredninger:* **1972: 44**, Oslo 1972

NOU 1977:31. Ressursregnskap. *Norges offentlige utredninger:* **1977: 31**, Oslo 1977

NOU 2001:2. Retten til miljøopplysninger. *Norges offentlige utredninger*: **2001:2**, Oslo 2001

NOU 2001:7. Bedre kommunal og regional planlegging etter plan- og bygningsloven. Planlovutvalgets første delutredning. *Norges offentlige utredninger*: **2001:7**, Oslo 2001

NOU 2001:35. Forslag til endringer i reindriftsloven. *Norges offentlige utredninger*: **2001:35**, Oslo 2001
NOU 2002:9. Jordskifterettenes stilling og funksjoner. *Norges offentlige utredninger*: **2002:9**, Oslo 2002
NOU 2004:28. Lov om bevaring av natur, landskap og biologisk mangfold (Naturmangfold-loven). *Norges offentlige utredninger*: **2004:28**, Oslo 2004
NOU 2005:5. Enkle signaler i en kompleks verden. Forslag til et nasjonalt indikatorsett for bærekraftig utvikling. *Norges offentlige utredninger*: **2005:5**, Oslo 2005
Rao, P.S.R.S. 1988. Variance estimation in sample surveys. In P.R.Krishnaiah and C.R.Rao (eds.) *Handbook of statistics, Vol 6, Sampling*. pp. 427-447, Elsevier, Amsterdam
Rekdal, Y. and Larsson, J.Y. 2005. Veiledning i vegetasjonskartlegging. *NIJOS rapport:* **01/05**, Ås 2005
Rekdal, Y. and Strand, G-H. 2005. Arealrekneskap for Norge. Fjellet i Hedmark. *NIJOS Rapport:* **06/05**, Ås 2005
Schøning, P. 1993. Arealstatistikk 1993 : en sammenstilling og vurdering av tilgjengelig arealstatistikk som plattform for videre arbeid på området, *Notater fra Statistisk sentralbyrå*, **93/44**, Oslo 1993
Scott, J.M., Davis, F., Csuti, B., Noss, R., Butterfield, B., Groves, C., Anderson, H., Caicco, S., D'Erchia, F., Edwards Jr., T.C., Ulliman, J. And Wright, R.G. 1993. Gap Analysis: A Geographic Approach to Protection of Biological Diversity, Wildlife Monographs No. 123. Supplement to *The Journal of Wildlife Management*, **57:1**
SSB, 1981. Ressursregnskap. *Statistiske analyser* **46**, Statistisk sentralbyrå, Oslo 1981
Steensgaard, K. and Strand, G-H. 2005. Innstruks for kulturminneregistrering i AR18×18. *NIJOS Document:* **56/05**, Ås 2005
Steinset, T. 2006. Dokumentasjon av Landbruksundersøkelsen 2004. *Notater fra Statistisk sentralbyrå* **2006/5**, Oslo 2006
St meld nr 17 (1998-1999) Verdiskaping og miljø - muligheter i skogsektoren (skogmeldingen)
St meld nr 19 (1999-2000) Om norsk landbruk og matproduksjon
Strand, G-H. 1997. CORINE Landcover: Evaluering, bruk og tilpassing til norske forhold, *Kart og Plan* **57**: 210-218
Strand, G-H. 2002. Landsdekkende og representativ arealstatistikk, *Kart og Plan* **62**: 38 - 41
Strand, G-H. and Rekdal, Y. in press. Nasjonalt arealrekneskap – utprøving i fjellet i Hedmark. *Kart og Plan:* **65:**236-243
Sæbø, H.V. 1983. Land use and environmental statistics obtained by point sampling, *Artikler frå Statistisk sentralbyrå* nr. **144**, Statistisk sentralbyrå, Oslo 1983
Sæbø, H.V. and Engebretsen, Ø. 1979. Metodehefte nr. 24 : Tre notater om punktsampling. *Arbeidsnotater fra Statistisk sentralbyrå*, **79/6**, Oslo 1979
Thompson, S.K. 2002. *Sampling. Second edition*. John Wiley & Sons, New York
Young, A. 2000. *Land resources: Now and for the future*. Cambridge University Press, Cambridge
Ødegaard, R.S. and Sickel, H. 2005. Satellittdata til kartlegging av arealdekkeendringer – en utprøving av metodikk for utvalgte inngrepstyper. *DN utredning* **2005-8**. Trondheim 2005