Land Cover and Land Use Classification Using TER-UTI

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ABSTRACT: In order to monitor the evolution of land use, the French Ministry of Agriculture began carrying out area frame surveys in 1946. The current survey, "TER-UTI", has been carried out since 1969. This survey consists of detecting land cover and land use on the ground around points represented by crosses on aerial photographs. The sample consists of 15,449 photos enlarged to a scale of 1:4000, with a square grid of 36 points drawn on each of them. The actual observed area around the point is about 10 m² in homogeneous tracts. The field work is carried out annually from May to July. Each point is classified according to a physical classification, which describes the land cover (82 headings), and a functional classification, which describes the land use (25 headings).

1. Land Cover/Land Use Monitoring within the French Statistics System

The statistics system is a component of the information systems that must be implemented to meet the needs of the users/deciders. This system uses two ways: (1) counting of production units on the basis of list frames, and (2) mapping or area frame sampling as regards land use/land cover.

A knowledge of Land Use/Land Cover is essential to the monitoring of agriculture in its temporal and spatial dimensions. That monitoring is a global need expressed by various politic or economic agents — administration, politicians, farmers, etc.

1.1 First Attempts at Land Use Monitoring

The major part of the statistical data about agriculture is collected by interrogation of the farmers (Agricultural Census, Structure Surveys, specific crop or animal surveys). The sampling frame is the exhaustive list of the units defined as farms, and the sampling unit is the farm. These surveys give estimates of the acreages attached to the farms, which account for about two thirds of the national territory — almost all the utilized agricultural area, a large proportion of fallow land, moors and heathlands, but a smaller percentage of woodland, and an even smaller percentage of non-agricultural area. Other surveys, such as the National Woodland Inventory (*Inventaire Forestier National*) give information about the area which is not attached to the farms, but the methods and the objectives are different, and the results are difficult to compare.

The Ministry of Agriculture, however, needs estimates of all the types of land cover, especially to monitor the change between agricultural and non-agricultural land — recession of market gardening around big cities, change of the fallow land into woodland, etc. To obtain these estimates, a specific survey is necessary.

The first experiments were carried out with the tools that were available in the late 1940s, mainly cadastral maps. The objective was an exhaustive mapping of all tracts appearing on the cadastral maps (1946 to 1969), noting the land cover and the acreage of each plot. The complete coverage of the national area was expected to be carried out in 10 years.

Difficulties arose rapidly from the poor quality of the cadastre and the difference between agricultural fields and cadastral plots, and aerial photographs had to be used in towns where the cadastre was unusable. On the other hand, it soon became clear that the evolution of the land cover was not easy to monitor with this method, because, due to splittings or mergings, the shape and size of fields often change from year to year, and because an interval of ten years between two surveys of each field was too long.

To cope with this difficulty, a sample of points was overlaid on the documents (cadastral maps or aerial photos), and the evolution was monitored every year on these fixed points. This was the beginning of the substitution of aerial photographs for cadastral maps as the basis of ground survey documents, which eventually led to TER-UTI.

1.2 The TER-UTI Survey

TER-UTI is based on the observation of areas designated by points in square segments drawn on aerial photographs. (Only the points are drawn. The segment limits are not materialized.) The objectives of this survey are:

- to provide a stable system of monitoring the evolution of the agricultural and non-agricultural territory — crop rotation, changes of the land cover;
- to give yearly data at the level of *départements* (basic administrative division of the territory whose area is about 6000 km^2) and regions; and
- to provide an area sampling frame for specific statistical studies.

The method associates the use of aerial photographs, which materialize the sampling frame, and the collection of information in the field by enumerators who use the photographs as topographic field documents. The main stages are as follows:

- choice of the aerial photos and location of the photos on a topographic map (indoors),
- location of the points on the ground, observation and classification of the points (outdoors), and
- codification and filling in of the questionnaire (outdoors and/or indoors).

Mainly to meet the requests of the European Union, which is eager to get early acreage estimates, the target date for the beginning is the 1st of May, although the vegetative state of the crops does not yet allow the identification of all land covers, especially in fields which have not been sown and are classified as “bare land” or “unknown”. The objective is ending the survey by the end of June to provide first estimates of the national area statistics. Semi-definitive results are available in August, and definitive results in September.

The data are entered at the local level, and conveyed to the national data processing workshop through the telecommunications network.

The field of the survey is land cover/land use, agricultural or not. As a consequence of this, the national territory has not been stratified according to the type of land cover or land use.

2. Sampling Scheme

2.1 Sampling of the Primary Sampling Units ("TER-UTI Grids")

The sampling scheme is simple. The national territory has been divided into square blocks of 144 (12×12) km^2, in which have been systematically selected 4 "theoretical" positions (8 in a limited number of small *départements*). The result of this procedure is that the "theoretical" positions are drawn every 6 km on a regular grid in the north-south and east-west directions. What could be considered as a two-stage sampling (blocks and positions within the blocks) boils down to the one-stage sampling of a position every 6 km, because of the systematic sampling in each block.

The Primary Sampling Units are square segments whose centres lie at the "theoretical" positions defined as above. In fact, the actual position of each segment does not exactly match its "theoretical" position, because the ground survey document is taken from the central part of an aerial photo of the standard coverage of the National Geographic Institute. It is the photo whose centre is the closest which is selected, provided that it is recent enough.

Although they actually are segments, the PSUs are usually called "TER-UTI grids" or "TER-UTI photos".

2.2 Sampling of the Secondary Sampling Units ("TER-UTI Points")

In each segment is carried out a subsampling using a regular grid of 6×6 points overlaid on it. The points are the Secondary Sampling Units.

On each aerial photo has been overlaid a square grid of 36 points, 300 m apart, by superimposing a grid of points on the negative of the aerial photo. Each point is represented by an overlaying cross.

For cost reasons, the photos are not geometrically corrected. The choice of the photo whose centre is the closest of the theoretical position minimizes the distortion, but there remains some distortion, and the actual scale is not exactly the nominal scale of 1:4000. This is of no consequence for the statistical calculations, but it makes more difficult the use of these data in a Geographic Information System (GIS). It must be remembered that when TER-UTI began, there was no concept of GIS, and the sample was not designed with the purpose of being included in such a system. Such an inclusion has been under consideration for some years only.

3. Observation Rules

The work of the enumerator consists of finding the location of the photo on a topographic map, going to the place of the photo, and finding the exact location of each point before observing the portion of territory generated by each point. Having reached the vicinity of the point, the enumerator may have some doubts concerning the exact location because of the inaccuracy of the documents or the complexity of the landscape. In that case, the enumerator points out a position with reference to local landmarks (remarkable tree, lane junction, etc.) This must be documented in order to allow a possible other enumerator to observe exactly the same place.

Theoretically, the point has no dimension. Nevertheless, it is important to give a definite size to the point. In fact, four areas are linked to the point: (1) point size, (2) circular extended point size, (3) polygonal extended point size, and (4) point value, or expansion factor.

3.1 Point Size

The point size is the area of the smallest part of the territory homogeneous and identifiable from the cross on the photo. Theoretically, the point has no dimension and could have an infinitesimal size. It is obvious, however, that the scale of the covers that are surveyed is defined at a metric scale, not a centimetric one. For instance, in a maize field, we do not make the difference between the rows of maize and the bare land between them — both areas are classified under maize.

This size has another limit — the definition of the photo enlarged to 1:4000. This leads to consider that the point was a small area of about 9 m² around its theoretical position. This area must be homogeneous with respect to the physical position and clearly attributed to the point designated by the cross on the photograph.

Points located on tract limits account for many ambiguous cases. The common method to solve the problem is the random selection of one of the two adjacent tracts. This selection is made for the whole duration of the survey, in order to maintain the stability of the sample.

In the case of a point located on the limit between a road and a cultivated field, the enumerator, thinking that points in agricultural areas are more useful, could create a bias in favour of agricultural land use, by choosing systematically the agricultural side of the border. In order to avoid that bias, the selection is carried out in the office of the supervisor and not by the enumerator.

3.2 Circular Extended Point Area

In some cases, the land cover is homogeneous at the metric scale (i.e. an area of 9 m² is homogeneous), but is heterogeneous at a decametric scale (i.e. an area of 100 m² around the point is heterogeneous). This is the case, for instance, in lowly wooded areas where grassland is interspersed with isolated trees or thickets. Here, the land cover is not the land cover of the 9 m² point, which could be individually classified as wooded area or bush or grassland, but a synthetic concept depending on the respective proportion of each land cover type. Other common heterogeneous areas in France are the poplar groves associated with other land use and several areas of fruit trees (e.g. six species mixed orchard) or under fruit trees (e.g. grassland under fruit trees).

Transition areas under focus are parts of the Utilized Agricultural Area which become parts of the non-agricultural domain due to urban and industrial growth and farmland abandonment. In this last case, the land cover gradually evolves from ungrazed grassland to scrub fallow land and, eventually, woodland.

In all these heterogeneous zones, the observation area is a circle whose radius is 15 m (700 m²).

3.3 Polygonal Extended Point Size

Most of the landscape is structured by fields, and the information obtained on a point is not only valid for the 9 m^2 circle, but is also valid for all fields in which the point is included. Field limits can already be included in a Geographic Information System (GIS), or can be drawn interactively on the computer screen on satellite images, or can be automatically generated by segmentation algorithms, in order to transform point information into field information.

4. Nomenclature

Each point is classified according to a physical classification that describes the land cover, and a functional classification that determines which socioeconomic functions the portion of land belongs to and describes the land use. The nomenclature has a general purpose and is not limited to agricultural area. Nevertheless, it was basically designed to give more details on agricultural areas and transition areas than on non-agricultural areas. The consequence is that the TER-UTI nomenclature is not always consistent with the nomenclatures used by environmentalists, town planners, and others.

TER-UTI is an objective survey, which means that the enumerator is supposed to note what he or she sees, but not to ask the farmer in dubious cases. For instance, a field of maize will be classified as maize and not grain-maize or fodder-maize, because this information is seldom available in the field. A field of rape in the "set aside" programme will be classified as rape, because it is not possible to tell from the field observation if it will be used to produce edible oil or for other industrial purposes.

Some land covers, however, can only be defined after an observation on a period of several years (see *Transition Areas* below), but the observation remains objective.

4.1 Physical Nomenclature (Land Cover)

The physical nomenclature divides the land cover into five major groups: (1) permanent waters and wetlands, (2) rock, pebbles and sand, (3) wooded area, (4) utilized agricultural area, and (5) artificialized area. These groups are broken down into 82 headings. (See Annex 1.)

Each physical code is a two-digit number, to which may be added two other digits to indicate further information. For example, *27-wheat* can be broken down into second-level codes *2710-soft wheat* and *2720-hard wheat*. These second-level codes have been set up at the national level. Their use is optional, depending on the information needs of the local statisticians.

4.1.1 Transition Areas — Wooded

Wooded areas often evolve from deciduous trees to coniferous trees. The major difficulty is the estimation of the respective proportion of deciduous and coniferous trees in the 700 m² circle, which needs particular attention from the enumerator. Particular instructions are given to the enumerator to help him solve the ambiguous cases.

Wooded areas may result from the evolution of fallow land.

4.1.2 Transition Areas — Grassland and Other

For a long time, grassland has not been considered as important a subject as arable land, whose production is often considered strategic. On the other hand, land abandonment is now a major issue, and the transformation of grassland into fallow land must be studied as an aspect of land abandonment. In order to have a better knowledge of these phenomena, the nomenclature of grassland has been expanded to allow for a finer analysis of the different types.

Code 46, *Leguminous grass or grazing*, has been broken down into *4611-purple clover*, *4621-alfalfa*, and *4631-other leguminous plants or mixture*.

Code 47, *Temporary grassland*, which is part of arable land, is defined as having been sown for less than six years with grass (*graminae*). This category is broken down as *4711/2-Italian Ray-Grass*, *4721/2-other pure grass*, and *4731/2-association of graminae*.

Code 48 is *Permanent grassland*. The grass is wild or was sown more than ten years before. It can be the result of the evolution of *Leguminous grass and grazing* or *Temporary grassland*.

The theoretical duration of *Leguminous grass and grazing* may extend over 10 years, but in case it gradually gets mixed with cultivated fodder *graminae* and/or weeds, it becomes *Temporary grassland* if sown less than 6 years before, or *Permanent grassland* if sown more than 6 years before. In order to monitor these changes, from 1990 onwards, the sowing date of new fields of *Leguminous grass and grazing* and *Temporary grassland* has been mentioned by the enumerator on the questionnaire.

Temporary fallow (52, in French *jachère*) is an area of arable land included in the crop rotation which is not harvested. It can have an aspect of: (1) bare soil — the land shows traces of recent tillage with little spontaneous vegetation; (2) new growth of the preceding crop — weeds are abundant (cover may have been cut and ground); or (3) land planted with species allowed by the "set-aside" regulations of the Common Agricultural Policy.

If it has not been used or looked after (grinding, grazing) for more than one or two years, the *Temporary fallow* becomes *Fallow land*. But if there is evidence of grinding, grazing, and especially tilling and burying of ground plants, the land can be classified as *Temporary fallow* for many years.

Fallow land (69, in French *friche*) is land which has not been used for agriculture for several campaigns. It is still possible to use it again. There are obvious traces of former agricultural use, or the plots are surrounded by arable land. From the immediate environment, it is possible to tell the difference between *Fallow land* and *Urban Waste Area*.

In *Fallow land* that was formerly under permanent crops (orchard, vineyard, etc.), the absence of pruning and weed control are good indications. *Permanent grassland* becomes *Fallow land* if it has not shown signs of use for two years. This abandonment will bring about the development of ligneous or semi-ligneous plants (brambles, ferns, gorse, broom, bilberry, blackthorn, hawthorn, juniper, wild rosebush, heath, etc.) The *Fallow land* will eventually become a *Moor*.

Moors (70) are large-scale landscape units where the development of the ligneous plants mentioned above exceeds a threshold of 25 percent. The percentage of trees is below 10 percent. Otherwise the land will be classified as wooded area. There is only occasional agricultural use, if any.

4.2 Functional Nomenclature (Land Use)

The functional nomenclature describes what each portion of land is used for under 25 headings. (See Annex 2.) Often, the information about the function is redundant with the physical code, but there are some exceptions, especially in transition zones (evolution towards fallow land or urban area). For example, for broadleaf woodland, the appropriate heading could be *4-timber production* or *20-sport and outdoor leisure activities*. An experimental field belonging to a research institute or a vocational school will be classified under *16-education and research*.

The determination of the land use is objective, often from the visual observation of the environment of the point. In that case, the eye of the enumerator is often better than any remote sensing device.

5. Quality Control

Two forms of control are carried out — consistency control and systematic control.

Consistency control consists of checking that the land cover is consistent with the land cover for the previous year. For instance, it is very unlikely that a field of wheat will become a wooded area or a vineyard. These cases are checked by a supervisor indoors.

Systematic control is a control of four points randomly selected on one out of four photos.

Three types of errors are met: (1) location error (the enumerator located the point in a wrong place), (2) observation error, and (3) interpretation error (misunderstanding of the instructions for particular cases). When a location error is found, further information is given in order to make the location of the point easier.

The aim of the control is not to estimate the error rate, but to correct the errors. To that purpose, the surveyors focus their control on areas where errors are expected. In each *département*, error matrices are produced, which give information on the most common causes of error.

6. Extrapolation of the Results and Calculation of the Sampling Error

The expansion factor, which we also call "value", of the TER-UTI point is given by the ratio of the area of each *département* as measured by the National Geographic Institute to that purpose and the number of points in that *département*. The value of the point is approximately 100 hectares.

The calculation of the sampling error considers that there are two sampling stages: (1) systematic sampling of the segments (photos), and (2) sampling of the points within each segment. The total variance on the acreage estimate of a given category of land cover is appreciated by the sum of the variance between segments and the variance within different points of each segment.

To give some examples, at a confidence interval at the probability threshold of 95 percent, the precision at the national level is (1996 data):

- 1.18 percent for woodland,
- 1.34 percent for wheat,
- 13.04 percent for apple orchards, and
- 2.12 percent for roads.

The precision increases when the estimated area increases, but it also depends on the homogeneity of the spatial distribution of the considered land cover type over the territory.

7. TER-UTI as a Source of Ground Data for Remote Sensing and GIS

TER-UTI is fundamentally a statistical survey. This means that the purpose is not to give a cartographic representation of the land cover, although it is possible to illustrate the distribution of a specific land cover on the national territory on a small-scale map (1:4,000,000).

TER-UTI was not designed to be used with a GIS or remotely sensed data. At the beginning of French remote sensing projects, it was practically excluded to use TER-UTI as a source of "ground truth" because the resolution of the Landsat MSS sensor did not allow the accurate location of a point in a

Landsat Frame. Improved satellite resolution provided by Landsat TM and SPOT, combined with progress in computer processing of geographic data, changed the context and brought up the possibility of using TER-UTI data again.

At the beginning, the problems in positioning the points and generating training fields have been dealt with by the development of specific programs generating square blocks of radiometrically homogeneous pixels around the points. Now, it seems more efficient to use polygon files of the field limits archived in a GIS, or to delineate those limits on the screen. The results are as good as those obtained from square segments, and remote sensing may be profitably used to increase the precision of TER-UTI in areas where a better precision is needed. Nevertheless, this application will remain exceptional.

In the future, it is contemplated to use very high resolution satellite data to draw a sample of geo-referenced points and to make the ground survey documents. This will make easier the combined use of ground data and remotely sensed data.

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Annex 1: Physical Classification

Permanent waters and wetlands

11 Salt marshes and brackish swamps
12 Lakes, fresh water ponds
13 Rivers (including estuaries), canals
14 Swamps, humid zones (including marshes and peat bogs)
15 Glaciers and everlasting snow

Rock, pebbles, sand

16 Rocks, boulders
17 Dunes, beaches with sand or shingle

Wooded area

18 Deciduous trees
19 Coniferous trees
20 Deciduous forest evolving towards coniferous forest (changed in 1993)
21 Mixed forest
22 Copses
23 Scattered trees
24 Poplar groves
25 Poplar groves associated with other land use
26 Scattered poplars

Utilized Agricultural Area

27 Wheat
28 Barley
29 Oats
30 Maize
31 Rye
32 Maslin and other mixed cereals
33 Sugarbeets
34 Textile crops
35 Sunflower
36 Rape
37 Other oilseeds
38 Other industrial crops
39 Potatoes
40 Peas and green peas
41 Broad beans and field beans
42 Other vegetables
43 Tree nurseries, flower, ornamental plants
44 Fodder root crops
45 Other annual fodder crops
46 Leguminous grass or grazing
47 Temporary grassland
48 Permanent grassland
49 Mountain grassland (*Alpages*)
50 Low-productivity grassland
51 Grassland under fruit-trees
52 Temporary fallow
53 Apricot trees
54 Cherry trees
55 Peach trees
56 Plum trees
57 Pear trees
58 Apple trees
59 Mixture of 53 through 58 (six species mixed orchard)
60 Other fruit trees
61 Association of six species mixed orchard with non-fruit crops
62 Association of 60 with non-fruit crops
63 Vineyards
64 Association of vineyards and six species mixed orchard
65 Association of vineyards and other crops
66 Berry bushes
67 Vegetable kitchen gardens
68 Lawn and other grass area
69 Fallow land
70 Moors
71 Sclerophyllous vegetation (*garrigue*, *maquis*, merged with 70 in 1993)
72 Hedges

Artificialized areas

73 Non-surfaced roads
74 Building sites
75 Other land covers altered by extraction (quarries, etc.)
76 Other land covers altered by deposits (rubbish dump, etc.)
77 Graveyards
78 Urban waste grounds
79 Farm yards, annex farm buildings
80 Surfaced areas under trees
81 Surfaced areas without cover
82 Surfaced linear features (roads, etc.) under trees
83 Surfaced linear features (roads, etc.) without cover
84 Association of different non-agricultural elements
85 Low covered and closed buildings
86 Tall or medium-height buildings
87 Greenhouses
88 Covered non-closed buildings
89 Temporary buildings
90 Other industrial buildings
91 Disused buildings including ruins
99 Forbidden areas

Annex 2: Functional Nomenclature

Primary production

1 Mining industry
2 Agriculture
3 Occasional agricultural production
4 Timber production
5 Fish production

Secondary production

6 Industry
7 Energy

Services and miscellaneous

8 Permanent road network
9 Railroad network
10 River or sea navigation
11 Air transportation
12 Other networks such as water distribution
13 Trade and services
14 Offices, administration and local communities
15 Military
16 Education and research
17 Culture
18 Places of worship
19 Social and health services
20 Sport and outdoor leisure activities
21 Individual dwellings
22 Collective dwellings
23 Rubbish dumps and other deposits
24 Protection of the environment
99 No use or temporary use