

## CROP AREA ESTIMATES WITH MERIS DATA ON BELGIUM AND POLAND

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### ABSTRACT:

In the framework of Geoland, Infoterra France has mapped with MERIS the distribution of annual crops surfaces in Belgium, Poland and Russia (Rostov oblast). The maps provided are the acreages of main groups of crops per administrative or agricultural circumscriptions unit. The groups are winter, spring and root crops (sugar beet, potatoes). The method for mapping exploits the MERIS capability to monitor large areas (~30 000 km<sup>2</sup> to 300 000 km<sup>2</sup>) and to measure frequently, twice per month as an average, the Fraction of Green Vegetation covering the soil. The temporal series of fraction of cover observed along the vegetation season is then compared to crops phenological models of the various groups of crops. An inversion based process calculates the proportion of the various groups of crops on the unit that covered by arable land. The produced maps have been evaluated with national agricultural statistics for the various covered area. The results obtained both on Poland and Belgium are presented here and are in general satisfactory. The methodology is relevant when agricultural conditions correspond to a bit of major crops within dominant agricultural areas. The only present limitation is the underestimation of Maize crops on Belgian case. However this performance should be tentatively improved in future versions of the processing chain.

### 1. INTRODUCTION

In the framework of Geoland, the Observatory for Food Security and Crop Monitoring (OFM) aims to contribute to the establishment of an independent pre-operational capability to provide near-real time information on crop conditions and cultivated areas in support of the assessment of local food security and global market prospects. In this context, the product that Infoterra France has developed and proposed is intended to serve estimation of major crops areas in region of the world where there is limited information available (Asia, Eastern Europe, Africa).

The maps of annual crop acreages serve two other main domains of applications: (i) the compliance with European Directives in relation with agriculture and agri-environment, namely the Water Framework Directive, the Nitrates Directive, the new agri-environmental pillar of the Common Agricultural Policy, and in the future the Strategy for Soil Protection, (ii) it is a valuable input for crop surface inventories required by administrations and for commercial purposes.

In the first case, the maps of annual crop acreages are used as inputs of scientific models to assess the impact of agriculture on the environment. This application has already been made with two water related models.

The service 'Regional maps of annual crop acreages' has been designed since year 2004, in collaboration with regional and national end-users, with the aim to support their obligation to fulfill European Environmental Directives and the Common Agricultural Policy (PAC). This methodology has been applied successfully for the estimation of irrigated areas for water management applications in other countries (France, Spain). The development has involved users from Spain (Ebro Catchment Authority, Ministry of Agriculture), three water

agencies from France (Adour Garonne, Seine Normandie, Rhin Meuse), the French Institute for Environment (IFEN),

German Landers (Saar and Rhein Pfalz) and finally the International Commissions for the Saar and Mosel.

Furthermore, Infoterra France has mapped in the year 2006 the distribution of annual crops surfaces on a total area of 700000 km<sup>2</sup>. This Meris based application can be exemplified as a pre-operational GMES service.

The developments of the service have been mainly funded in the frame of GMES by ESA, and the EC, complemented by national French programmes.

### 2. DEFINITION OF THE PRODUCTS AND SERVICE

The service provides the information of acreage covered by different crops categories. A figure (in ha) is provided per administrative or hydrographical unit of an average 10 km<sup>2</sup> size.

The categories of annual crops that can be mapped are the ones that can be separated thanks to their distinguishable development profiles. Examples are the winter crops, spring crops, summer crops, the pastures and also the "intermediate crops". This latter category refers to the crops cultivated in autumn and winter to absorb nitrogen surpluses left in soils and prevent their leaking to rivers.

Examples of maps are presented on Figure 1 and on Figure 2. The colour code indicates the range of acreages in the agro-circumscription or hydrological unit respectively. In order to show where arable acreages are, colours are applied solely to the mask of "arable land" Corine Land Cover (CLC) objects (classes 2.1.1 and 2.1.2). None "arable land" CLC objects are left in blank.

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This service is made to be delivered annually, either as a finalised product at the end of the crop season or as progressively refined maps at key dates during the growing season. The latter (figure 2) applies particularly for regions where summer irrigation is important and where water managers need to know the irrigated acreages during the irrigation campaign.

The product is generated from medium-resolution MERIS data by an operational and automatic production chain.

The MERIS sensor is very well adapted to covering large areas, which is the user's expectation. Thus the maps may cover a whole country, a basin or a sub-basin, i.e. an extent ranging typically from 7.000 to 300.000 km<sup>2</sup>. The elementary spatial unit of application (administrative or hydrographical) must be larger than 3 km<sup>2</sup> due to methodological constraints.

The small scale maps generated with MERIS are complementary to the large scale maps, classically obtained with high resolution sensors (SPOT, Landsat) and that identify crops within field boundaries.

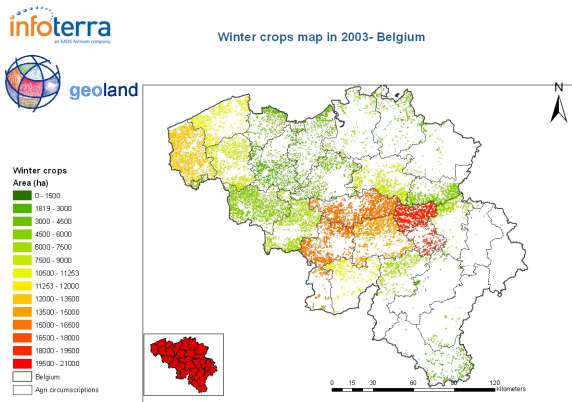


Figure 1. Winter crops acreage maps per agri-circumscription unit in Belgium in 2003.

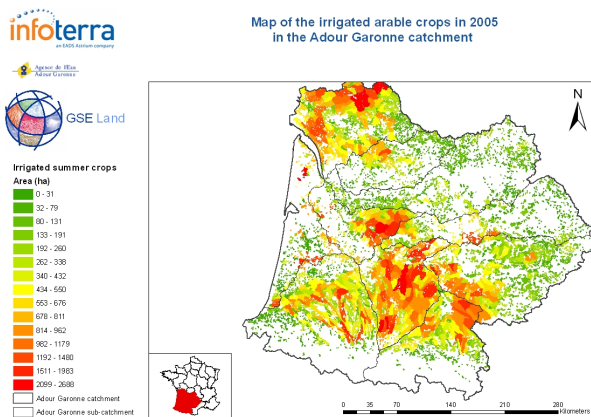


Figure 2. Irrigated summer crops acreage maps per hydrological unit in the Adour Garonne district in 2005.

### 3. METHODOLOGY AND PROCESSING CHAIN

The method exploits the MERIS capability to measure frequently, twice per month as an average, the Fraction of Green Vegetation (GLCV) covering the soil as well as the variance of this GLCV within each MERIS pixel, considered as a composite of vegetation and soil patches (variance : GCVV). The temporal series of GLCV, such as the one illustrated on Figure 3 on the Beauce region in France, and GCVV observed along the vegetation season, are averaged at

the scale of administrative or hydrographical unit, and are then compared to a model.

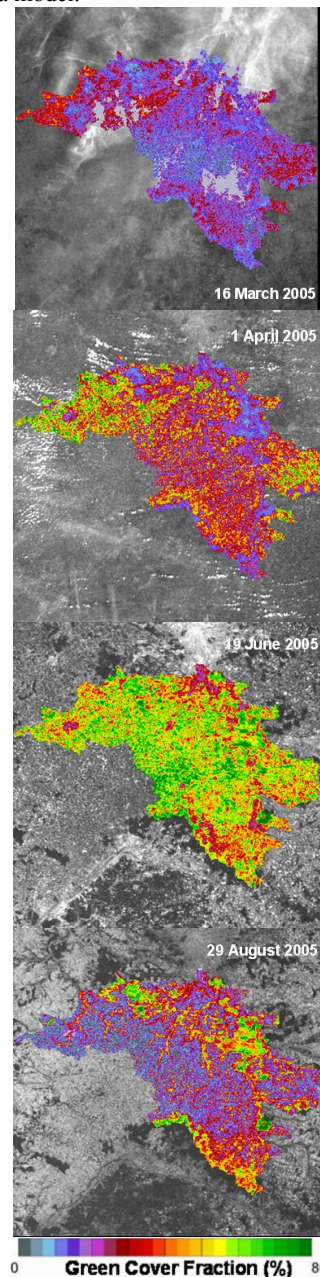


Figure 3. Evolution of GLCV in 2005 over the Beauce region (France)

From the set of biophysical images, we can see the evolution of GLCV along the seasonal campaign:

- Winter crops start developing highlighted in red (16th March),
- Winter crops development is speeding up, even areas less dense in crops are reddish (1st April),
- Winter crops reach their maximum greenness, summer crops start developing (19th June),
- Winter crops ripen (back to blue) whereas summer crops reach their maximum (29th August).

This model combines the phenological development models of the various groups of crops. This combination is illustrated on the Figure 4.

The models are driven by the meteorological conditions along the vegetation season, which therefore need to be provided.

Finally an inversion based process calculates the proportions of the various groups of crops in the unit that produce the best fit between the observed and modelled temporal composite profiles of GLCV and GCVV. In order to avoid mixing signals from the target (arable land) and from other types of covers (urban, forests, natural areas), the process is applied to the only MERIS pixels covered by arable land. An arable land mask is derived from a land cover information that can be Corine or a more detailed data base produced in the frame of GMES projects (GSE land or Geoland).

An operational processing chain has been developed in Infoterra France to process sets of MERIS data on regional scale. This chain includes the OVERLAND™ software for the generation of GLCV and GCVV. It is fully automatic and is based on the implementation of algorithms programmed with IDL and MATLAB languages, which guarantees the perfect reproducibility of the results. The processing chain has been certified by an external audit in the frame of the GSE land project.

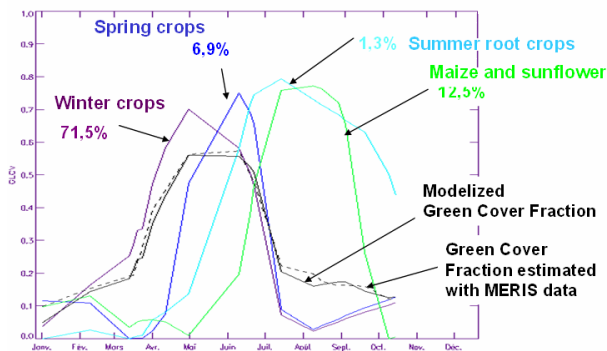


Figure 4. On a given administrative or hydrographical unit:  
 1) Individual modelled plots of GLCV's of various crop categories (winter, spring, summer root crop = sugar beet and potatoes, maize and sunflower).  
 2) The modelled plot of GLCV obtained by combining the individual models with given proportions of crops in the unit (winter crops 71.5 %, spring crops : 6.9 %, etc.).  
 3) The GLCV average profile estimated (observed) with MERIS represented in dotted line. The inversion process tunes the crop acreage percentages so that the modelled GLCV (crops combination) fits the observed one.

#### 4. RESULTS

The products on Belgium and Poland are illustrated on the figure 5-1 and figure 5-2 respectively. They are directly provided in GIS format. The spatial unit for Belgium and Poland corresponds to the agricultural circumscription units and administrative units (NUTS2) respectively. The surfaces are expressed in hectares. The arable acreages maps are illustrated by one colour per administrative (Poland case) and per agricultural circumscription (Belgium case) unit, spatialized thanks to the CLC mask of arable land. The three "Arable acreages maps" groups of classes discriminated by MERIS are (i) for the Belgian case, Winter (and Spring included) crops, Maize (and assimilated) and Root (sugar beet and potatoes) crops and (ii) for the Polish case, Winter crops, Spring crops, and Root (sugar beet and potatoes) crops.

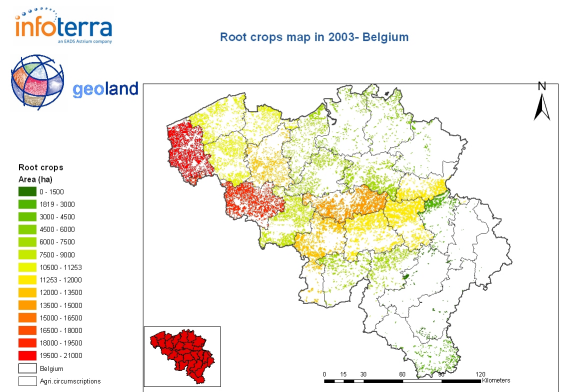
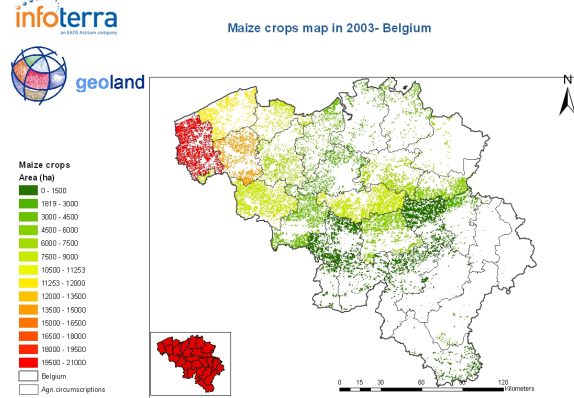
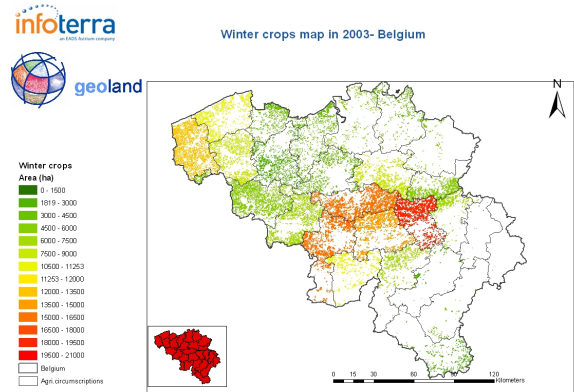
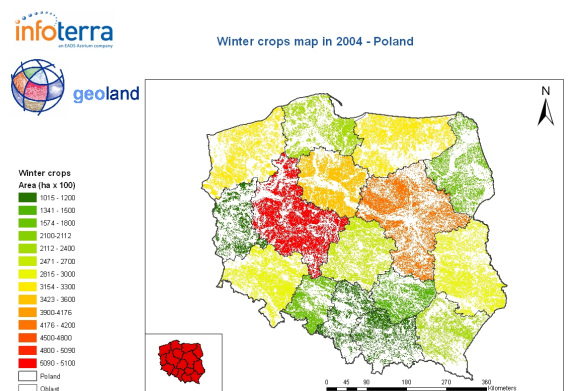


Figure 5-1. Illustration of arable acreages maps on the whole of Belgium in 2003: Winter crops, -Maize crops and Root (sugar beet and potatoes) crops.



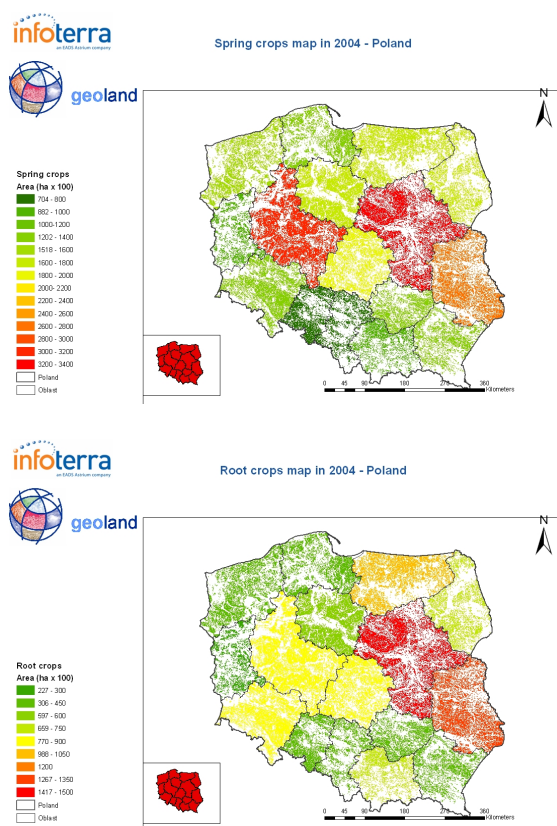


Figure 5-2. Illustration of arable acreages maps on the whole of Poland in 2004: Winter crops -Spring crops and Root (Sugar beet and potatoes) crops

#### 4.1 Criteria of validation

The evaluation of the results has been carried out by comparing them to one reference data base:

- Agricultural statistic database from IACS (Belgium case) and from IGIK (Poland case).

For the Belgian case, the types of crops distinguished in the "Arable acreages maps" product do not correspond to the crops identified in IACS database which is very detailed. Hence it has been necessary to group the latter types of crops in macro-classes that are identical to the three "Arable acreages maps" groups of classes: Winter / Spring crops, Maize (and assimilated) and Root (sugar beet and potatoes) crops.

Concerning the Polish case, major crops (sugar beet, oats, rye and winter barley) acreages information is missing in the Agricultural statistic database provided by IGIK. Consequently, the validation had to perform from information at national scale (provided by MOCA study-JRC).

##### 4.1.1 The average error on the complete area covered

The relative error, compared to agricultural data bases, is provided in the following table for the different cases that have been processed. The relative error equals to:

$$1 - \frac{\sum SIMULATION}{\sum DATA} \quad (1)$$

where *SIMULATION* and *DATA* are, for each of the three "Arable acreages maps" classes, the estimated

surface on the overall area and the surface reported by the reference databases respectively.

##### 4.1.2 The errors observed on the various spatial units of analysis

The performance of the product "Arable acreages maps" is evaluated through a statistic indicator (T): The T statistic is defined as:

$$T = 1 - \frac{\sum (DATA - SIMULATION)^2}{\sum (DATA - DATA)^2} \quad (2)$$

where *SIMULATION* and *DATA* are, for each of the three "Arable acreages maps" classes and per administrative (Poland case) or agricultural circumscription unit (Belgium case), the estimated surfaces and the statistical database respectively. *DATA* is, for each of the three "Arable acreages maps" classes, the average value of the acreage on the whole population of units.

The T statistic characterizes the equality of two variables and measures the scattering around the 1:1 line. A good performance of estimation is associated to T values close to 1.0. Conversely, poor performance will show low T values.

#### 4.2. Belgium case

The results in terms of errors are provided in the table 1. The T statistic and relative errors are presented hereunder:

Comparison with IACS database	Winter crops	Maize crops	Root crops
Relative error (%) (eq 1)	24	3.8	0.68
Relative error (%/total circumscription unit)	45	4.3	0.12
T calculated on the agri-circumscription unit (eq 2)	23	2.4	0.76

Table 1. Relative errors and T values characterizing the performance of Winter-Spring crops, Maize crops and Root crops (Sugar beet and Potatoes) from IACS database.

The error relative is then calculated from these values and reported in the table 1 (line 2).

The T values reach 0.76 and 0.68 (Table 1) for Root (Sugar beet and potatoes) crops and Winter Spring crops respectively, except the case of Maize crops (0.12). The relative errors are satisfactory for both Winter Spring and Root crops.

The results for the Maize crops are not as satisfactory as the other crops. The low value of T observed for Maize crops is due to underestimation of Maize for some high values (not shown). These errors might be explained by major factors:

The arable land area provided by Corine Land Cover is less important than this one provided by the agricultural statistic database in the districts where the maize fields are dominant (North-West of Belgium). Consequently, the surfaces estimated from MERIS are inferior to those estimated from agricultural statistic. In particular, this difference between Corine Land Cover and agricultural statistic database is found in the Maize class.

In addition, from a crop development point of view which is analysed with Meris, the patterns of the maize crops appear as similar to pastures. Indeed, a parallel study has shown that from high resolution satellite data, a drop of the GLCV signal on maize fields is observed after flowering phase. This effect has been emphasized due to the severe drought in 2003. Maize

crops may be identified like natural vegetation or/and pastures. Consequently, the distinction between these two classes of “crops” is difficult and the process tends to underestimate the Maize crops.

### 4.3 Poland case

Major crops (sugar beet, oats, rye and winter barley) acreages information is missing the Agricultural statistic database provided by IGIK. Due to this data gaps, it has been impossible so far to produce meaningful figures of acreages accuracy at administrative scale. In spite of this lack of data, the repartition between the groups of crops is respected and adequate (Figure 6). Otherwise, we obtain good results at national level (relative errors for each group of crops are very low, see table 2 and figure 7). The information at national scale is provided by MOCA study (JRC).

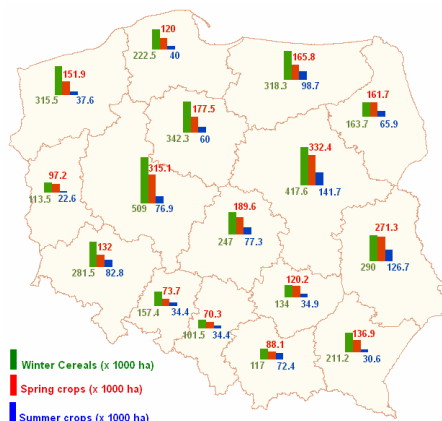


Figure 6. Repartition of three components of Arable acreages maps in 2004. Spring crops, Spring crops and Root crops (Sugar beet and Potatoes) are represented in green, in red and in blue respectively.

Table 2. T, Relative errors characterizing the performance of Winter crops, Spring crops and Root crops (Sugar beet and Potatoes) from MOCA database at national scale. T cannot be calculated due to the lack of data at administrative scale (IGIK database).

comparison with MOCA database	Winter crops	Spring crops	Root crops
Relative error (%) (eq 1)	4	15	8
T calculated on the administrative unit	NA	NA	NA

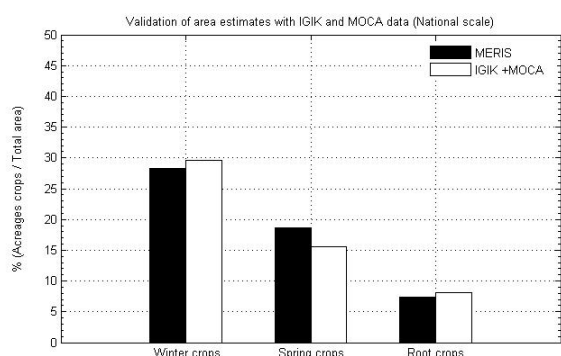


Figure 7. Proportion per crop (surface aggregated on the whole of Poland). In black bar is represented the values from MERIS and in white bar the statistical values mixed of IGIK and MOCA data. MOCA data are available at national scale.

## 5. DISCUSSIONS

The only problem for validation is the availability of reference data bases at administrative level (Poland case). In addition, the link between the agricultural statistic database and GIS compatible map of the agricultural circumscription units may not be 100% reliable (Belgian case). These limitations are always to be kept in mind in the process of validation.

The results that have been obtained are in general satisfactory and compliant with the specifications of the products. However two points need to be better understood through further developments:

Though this lesser performance (Belgian case) is not critical, this point needs to be improved in further developments. The performance improvement could be expected when the MERIS geometry problems are solved. The provision of upgraded 1P product by ESA is expected in the immediate future.

The difference between estimated surface and statistic data base is high for certain zones (North of Belgium) for the Maize crops. This can be explained on one hand, by a large difference between CLC and agricultural statistical databases and on the other hand by confusion between the temporal profile of maize crops and pastures emphasized by the drought in 2003.

This study demonstrates that the approach used is relevant when condition context corresponds to a dominant agricultural area with a bit of dominant crops. In return, the approach is limited when condition context is rendered difficult when land cover is fragmented and there are a lot of minor contributions of classes and crops. On the other hand, the results obtained on Poland demonstrate that the product developed and proposed is able to serve estimation of major crops areas in region of the world where there is limited information available like for example in Eastern Europe, in Asia and in Africa.

## 6. OPERATIONS CARRIED OUT IN 2006

In 2006, a large set of maps was produced in the frame of several GMES projects (GSE land funded by ESA, geoland funded by the EC, AGRIMOD funded by French Space Agency CNES). These maps, covering a surface of 700.000 km<sup>2</sup> and sketched on Figure 8 have been produced in Spain, France, Belgium, Germany, Luxemburg, Poland and Russia. This performance demonstrates the operational capacity of the production facilities.

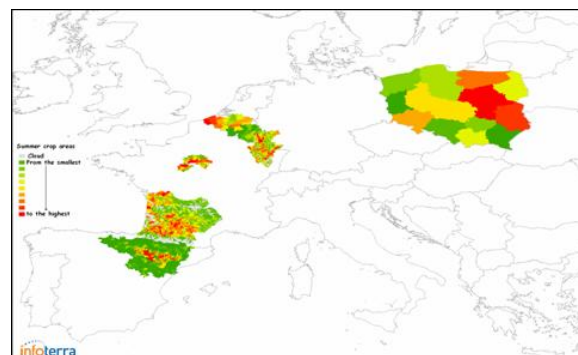


Figure 8. Annual crop maps produced in the projects of year 2006 for various types of users.

#### **7. CONCLUSION AND PERSPECTIVES**

Through the variety of regions covered in Europe and Russia, it has been demonstrated that the product is applicable to many types of climatic and phenological conditions and is therefore a truly pan-European product.

The annual crop maps generated with MERIS are complementary to the large scale maps, obtained with high resolution sensors (SPOT, Landsat) and that identify crops within field boundaries. The annual maps provide exhaustive spatial information and can then drive more detailed monitoring exercises that require high resolution sensors.

They provide also complementary information to the crops acreage maps obtained by Area Frame Sampling (AFS) statistics methods.

Finally these maps are produced at affordable and therefore attractive costs, around 0.5 €/km<sup>2</sup>, the cost of MERIS data being non significant in that amount.

#### **References**

Geoland OFM, 2007. Test & Benchmarks Report on Poland and Belgium..

GSE Land Web Page: <http://www.gmes-gseland.info/>