



# Aqua Soil SAGE

Service for the Provision of Advanced Geo-Information  
on Environmental Pressure and State

## ServicePROSPECTUS

ESA GSE Project on  
Water Framework Directive &  
Soil Thematic Strategy

## SAGE SERVICES & PRODUCTS AVAILABLE TODAY

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### INTRODUCTION

The project aims at the GMES priority themes “Environmental Stress” and “Land Cover”. The precursor services address the European Water Framework Directive (WFD) and the Soil Protection Initiative (SPI). In order to monitor and improve environmental conditions, the cardinal needs of planners and decision makers on available, reliable, and affordable information delivered in time on environmental pressure and stress have to be served.

The implementation of the new European policies WFD & SPI are a challenge to most legal bodies in charge. For example, the demand for water basin management plans addressed by the WFD, and reporting schemes on GIS basis requested from the EC, will impose a real paradigm change: instead of statistical data from sampling and point measurements (today’s standard approaches), spatial information on is increasingly required on national and local scales. In addition, the European Commission put strong efforts on harmonised reporting from the member states, which requires harmonisation of thematic content and data formats in order to make reports comparable at European level. Here, EO based geo-information data provided by SAGE will contribute significantly.

SAGE directly addresses the requirements of core users dealing with implementation of the WFD and SPI, and representing different environmental conditions (boreal, central European, Alpine, Mediterranean), different information levels (European, regional, national, local), and different end user-organisations (European Commission – European Environmental Agency (EEA), Ministries of Environment from member states and local end user groups; e.g. federal state ministries or regional water / soil authorities). Due to their high interest in SAGE, the core users actively participate in the project, their activities being coordinated by the European Topic Centre Terrestrial Environment (ETC-TE).

To serve the needs of many different end user-segments, which have been identified during the preparation of the SAGE proposal and the first months of the project, SAGE reflects:

- hot spot mapping or sampling approaches at local / regional level
- complete coverage in significantly reduced scales at international level
- different end user infrastructures; e.g. an agency which has an information service already installed and which likes to improve their service will request only for better landcover information, while other customers may ask for a complete service on agri-environmental risk maps or indicators for planning, control and response actions. SAGE pre-cursor services comprise
  - AquaSAGE with Water Quality, Water Shortage and Indicators (pressure & state indicators)
  - SoilSAGE with pressure and state indicators.

The key goal is to support the responsible authorities in establishing sustainable management of their water basins and their soils. A better understanding and the early detection of potential risks and sources of environmental degradation will contribute towards a reduction of costs for mitigation, maintenance and sustainable management of the environment as well. In addition, SAGE will be an important step towards a harmonized reporting scheme for the European Union as a whole.

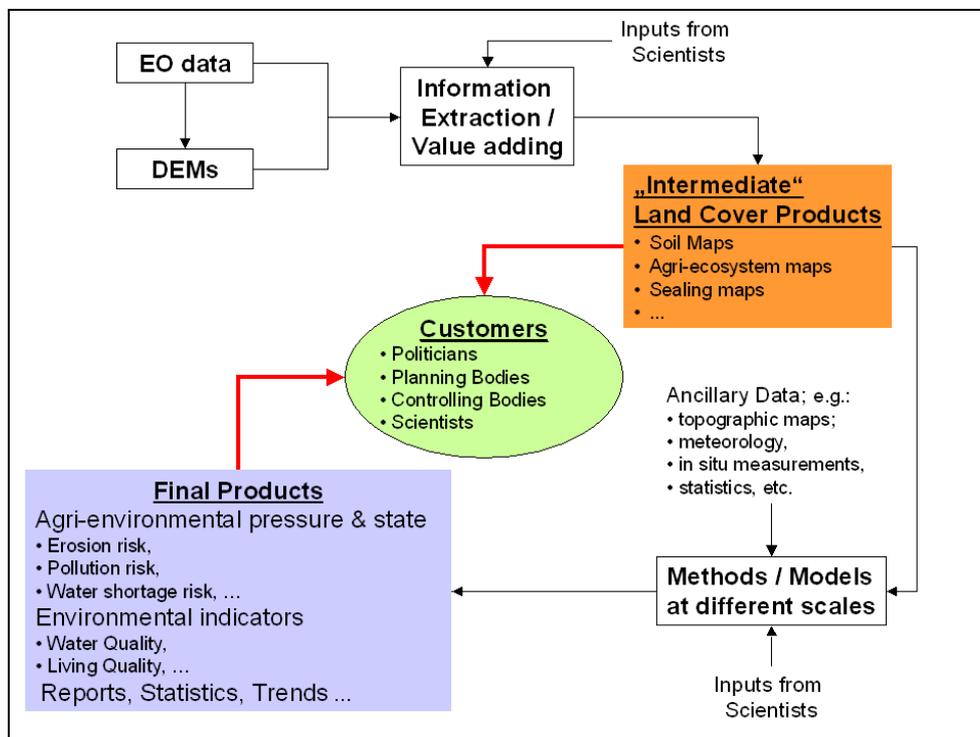
The salient features to achieve SAGE's objectives have already been identified by ESA and are recognised by the study team. They constitute the GSE's objectives and milestones:

- The involvement of end users for "closing the loop" between the operational results obtained from the present generation of EO satellites and the definition of future systems.
- The demonstration of EO based information precursor services which are based on proven technology and which are capable to deliver in time reliable and affordable information.
- The identification of cross-cutting issues of a GSE core service basis, addressing for instance a harmonised production chain for landcover / land use (LC/LU) information as "intermediate" products.

The technical realisation of SAGE is based on an open concept for both the infrastructure (space, ground and services) and the partner network. As an overall principle, the design first of all reflects the user needs translated into SAGE's product portfolio.

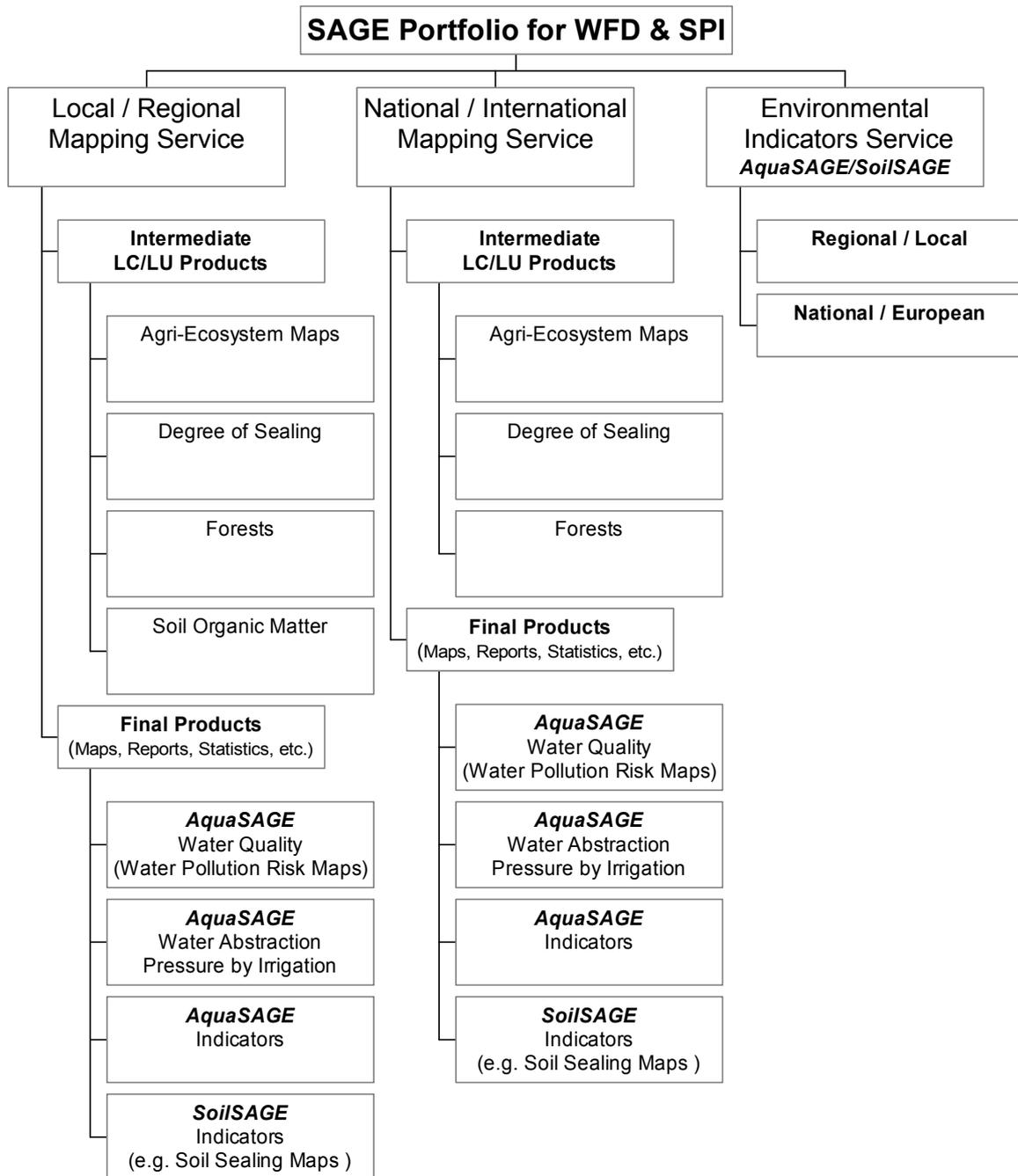
## AquaSAGE AND SoilSAGE SERVICE PORTFOLIO DESCRIPTION

The AquaSAGE and SoilSAGE service portfolio integrates EO-based Land Cover / Land Use (LC/LU) information and data from a wide range of other sources (e.g. terrestrial measurement networks, statistics, etc.) within quantitative models on water basin level and for environmental and planning issues related to soil sealing. In the image below a generic overview of the service value chain for SAGE is presented. It considers EO data and Digital Elevation Models (DEMs) as major information sources for land cover; here specified as “intermediate products” resulting from a standardisable core service. In combination with data from many other sources they will have to be combined and analysed at various levels and scales using for instance models for risk assessment or for the creation of environmental indicators.



*Overview of the SAGE service chain for land cover and agri-environmental information products*

In the following, products and services, which can be generated and delivered to users, are described in short. This provides a generic overview of the SAGE service portfolio for agri-environmental geo-information. The description starts with the generic core service to create intermediate products on LC/LU followed on top by the more specific services from the SAGE partners.

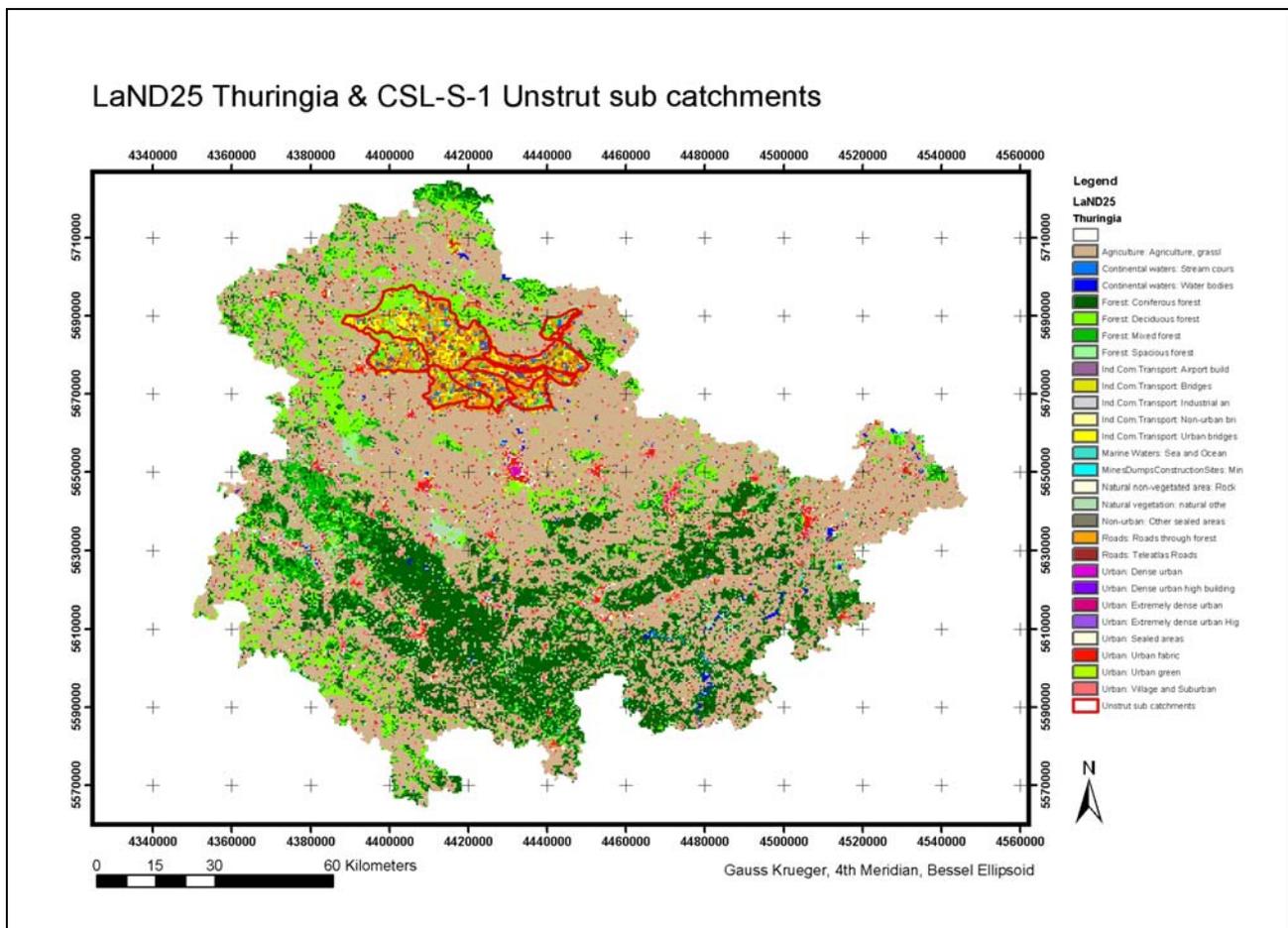


*Generic overview of the SAGE service portfolio for agri-environmental geo-information*

## Core Service – Generic Land Cover

### Products / Services Delivered Today

The objective of the core service is to provide generic land cover information to the regional service providers and to European and national entities in charge of monitoring environmental pressure and state. It is based today on a pre-operational production chain for high-resolution (up to 1:25.000) general and specialised (urban, forest, agriculture) land cover maps that allows more frequent large-area updates than with today's approaches (e.g. CORINE) and short-term hot spot monitoring at affordable costs.



*Example for a core service product generic land cover in scale 1 : 25, 000, with water basin specific information on agriculture intensity (CSL-S-1).*

## Methodology

The end-user needs on LC/LU are satisfied in a way, which is to a certain extent consistent with the CLC nomenclature, the only European standard on EO based LC/LU data bases. This assures that overall consistency and comparability are maintained as far as possible, and relevant information is delivered in a harmonised way.

As CLC is far from optimal for many end users working at regional / local level SAGE offers:

1. Identification of smaller land cover features (e.g. 1-5 ha resolution cells) by maintaining the thematic content,
2. Creation of higher level of detail of the thematic content (e.g. CLC level 4 and beyond) by maintaining the scale
3. Improving both, scale and thematic content

For this reason, a hierarchical approach is applied, following CLC nomenclature, as far as possible. LU/LC information is provided down to CLC level 3 in a standardized but significantly improved way according to EU definitions. This will assure the capability of up-scaling the results to national and international level and the possibility of integration into European LU/LC approaches. CLC "Level 4" items will be derived w.r.t. the specific national, regional or local user needs, but fitting into the overall CLC nomenclature as required from the CORINE program [EEA, 1995 & EEA, 2000].

## Today's Constraints

Besides data availability over long periods and large areas a critical issue is the lack of harmonised reporting schemes for geo-information data at European level. However, as far as the European Reporting Directive and INSPIRE are not in place it has to be assured by a "late customising approach" that national and regional special requirements from users can be met.

For a coherent production of LC/LU the European community of service providers includes an important number of institutions, but the community is fragmented and has not been organized to bridge the gap. It is fragmented in its applications and geographical scopes (often national), resulting in a disorganized duplication of activities.

## Major Benefits

EO based information on Land Cover / Land Use (LC/LU) is a cross-cutting issue because such information is mandatory for describing a multitude of environmental conditions. Hence, it's cost effective and sustainable provision to end user segments will improve significantly management and planning activities at all levels from European customers down to regional applications, by preserving time and money for the users and by improving output results from subsequent modelling approaches.

## AquaSAGE: Surface and ground water quality

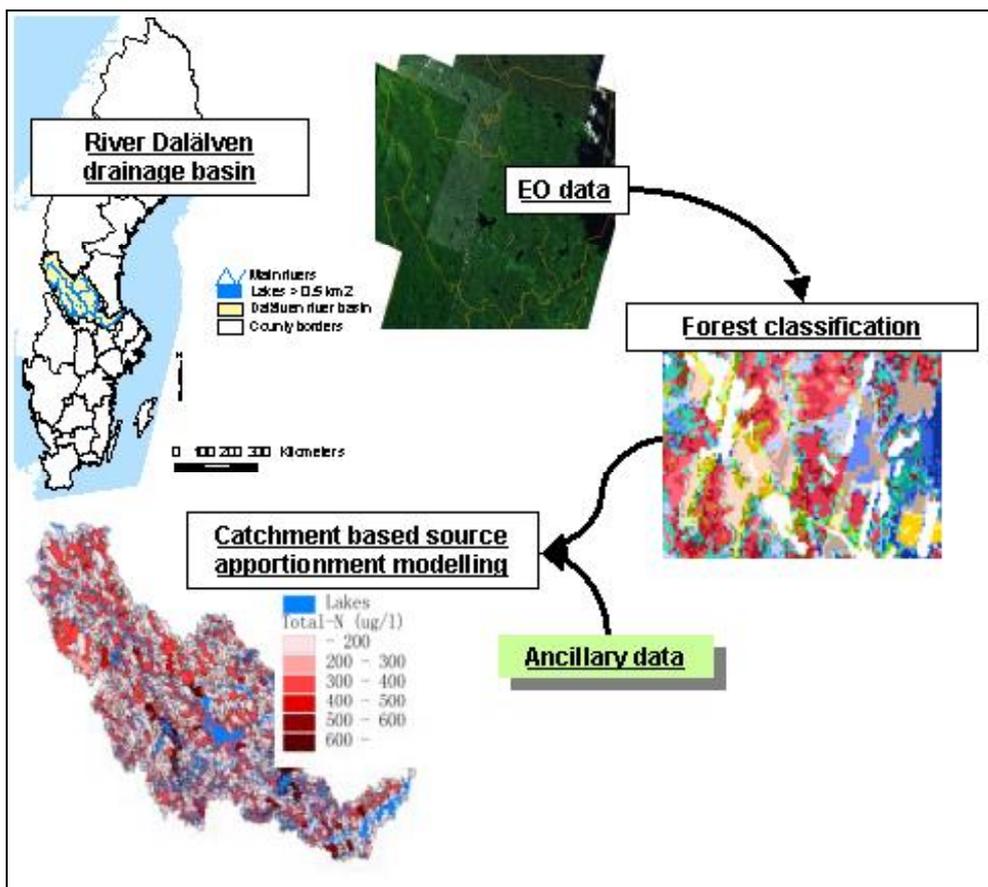
### AquaSAGE – boreal forests

#### Products / Services Delivered Today

The SAGE service “AquaSAGE – boreal forests” focuses on nitrogen leakage in the boreal zone. The forest indicators biomass, productivity and clear cuttings and the aquatic indicator nitrogen leakage are addressed. The service has been successfully applied to the river Dalälven drainage basin (29 000 km<sup>2</sup>) in central Sweden

The products provided by the service Aqua-SAGE for boreal forests are

1. Wall-to-wall datasets of forest indicators productivity, biomass and clear cuttings covering the river Dalälven drainage basin, as input to an
2. Improved source apportionment for nitrogen in the river basin, using specific models with the possibility of scenario studies.



Source apportionment from river Dalälven drainage basin (29 000 km<sup>2</sup>) in central Sweden, based on FYRIS source apportionment model and water quality maps.

The intermediate products (forest indicators) are primarily used as improved input to a refined source apportionment model for nitrogen in the drainage basin, i.e. the final product, but they may also be used for other purposes (e.g. terrestrial monitoring).

The final products from the service are the source apportionment for the river basin based on the source apportionment model (FYRIS model) and water quality maps.

## Methodology

The catchment characteristics will be based on official maps and the intermediate products, i.e. the improved spatial information on forest indicators. Ancillary data used in the modelling will be data on e.g. point sources, nitrogen deposition, runoff and land use (other than forest).

For clear cut mapping, a methodology for change detection is used, developed and implemented in a software tool within the ENFORMA project (EC FP4 project ENV-CT97-0423).

For mapping of forest biomass and productivity a classification of tree species composition and age is applied which was specifically adapted for handling a mixture of reference data from different sources. The approach is non-parametric and the images are de-noised using wavelet-transformations. Estimation of biomass and productivity (growth) are then derived from the tree species classification.

## Today's Constraints

The areas to be covered in Scandinavia are large and the time period needed to cover a specific area, e.g. an entire drainage basin, varies depending on the availability of individual cloud free satellite scenes. The cloud coverage also affects the possible up-dating frequency which for monitoring purposes probably will have to be defined as an interval, e.g. target on every year for some purposes but allowing an interval 2 – 6 years.

The lack of suitable, cloud-free, scenes implies that in the future a stabilized service (the whole chain of satellite data processing, source apportionment, validation etc.) with up-dated deliverables will have to be able to handle data from different years in different parts of the drainage basin.

## Major Benefits

EO-based information will provide wall-to-wall data on forest indicators covering drainage basins. This will make it possible to incorporate homogeneous data with higher spatial and thematic resolution than presently available for use in source apportionment for example for the river Dalälven. It will also allow for a refined definition of element loss (nitrogen) from forest land. The data will be implemented together with ancillary data (GIS layers on sub catchments, monitoring data etc.) into the FYRIS source apportionment model, which in turn will provide an improved estimate of nitrogen leakage from boreal forests.

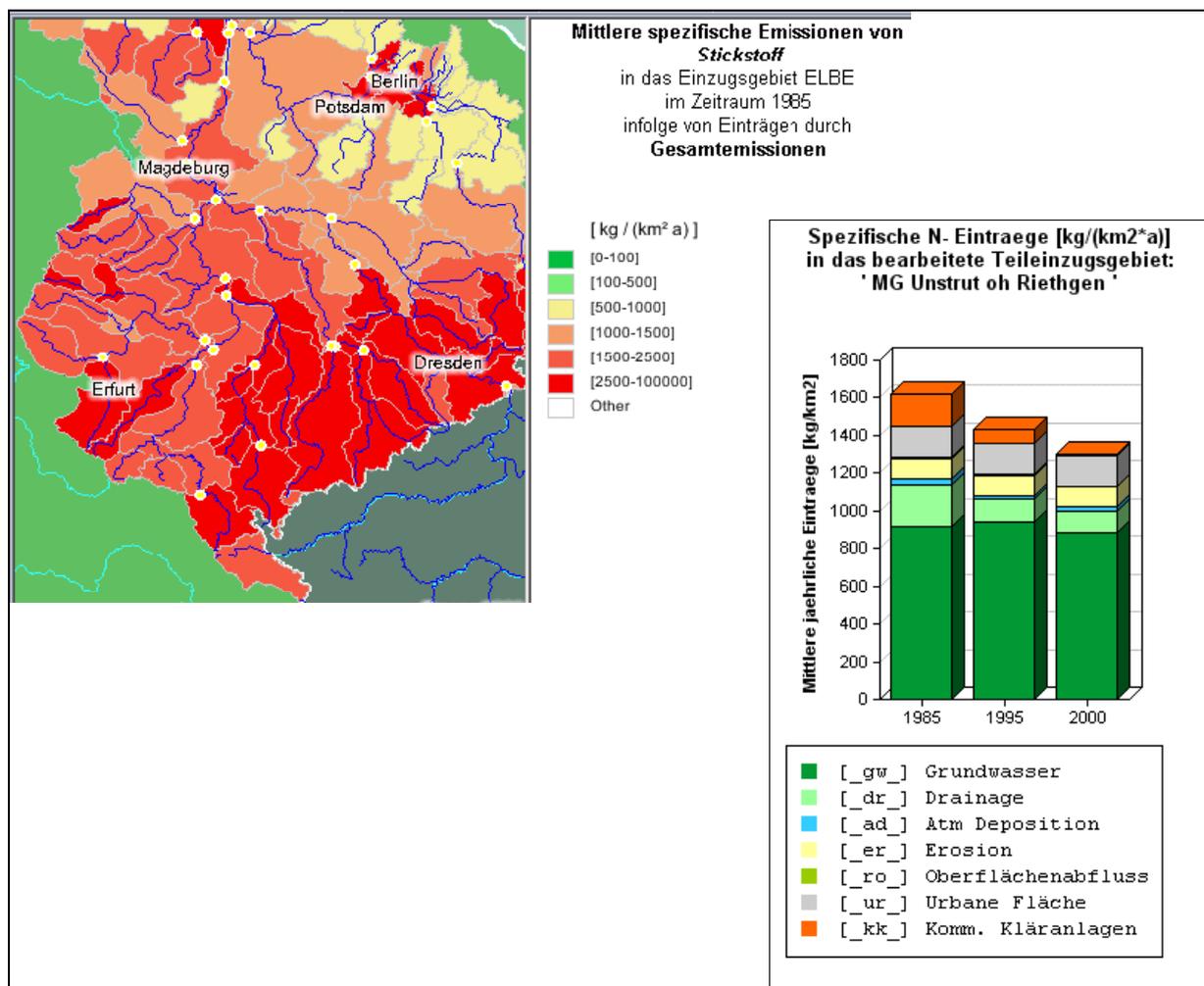
## AquaSAGE Central Europe

### Products / Services Delivered Today

The AquaSage service for Central Europe consists of maps and statistics qualifying and quantifying nutrient inputs into river basins. Basis of the service is the model MONERIS (MOdelling Nutrient Emissions in River Systems). The catchment based analysis allows either summary and differentiated catchment quantification of the main nutrient pathways. This analysis serves for identifying of regional focal points of nutrient pollution, which are prominently to be considered for the installation of measures for reducing inputs.

The service is delivered to the German Environmental Agency (UBA) and the Thuringian Institute for Environment and Geology (TLUG), both in charge for the reporting on water status and the installation of measures to conserve good water quality.

Examples of spatial and statistic results are shown in the following example.



Examples of spatial & statistic results from MONERIS model [© GIA, Dr. Pagenkopf; UBA]

## Methodology

The model MONERIS was developed and applied to estimate the nutrient inputs into river basins of Germany by point sources and various diffuse pathways. The model is based on data of river flow and water quality as well as a geographical information system (GIS), which includes digital maps and extensive statistical information.

Whereas point emissions from waste water treatment plants and industrial sources are directly discharged into the rivers, diffuse emissions into surface waters are caused by the sum of different pathways, which are realised by separate flow components. This separation of the components of diffuse sources is necessary, because nutrient concentrations and relevant processes for the pathways are mostly very different.

Consequently seven pathways are considered:

- point sources
- atmospheric deposition
- erosion
- surface runoff
- groundwater
- tile drainage
- paved urban areas

Most important input parameters are especially LC/LU information detailed to agricultural crop types which are provided by the SAGE core service.

## Today's Constraints

Besides availability of EO data in terms of large scale mapping of important LC/LU classes in reasonable time periods, another critical issue is the availability of harmonized additional data sets like statistics and thematic maps. A lot of work has to be done in preparation of input data while the modelling approach itself is settled. This is especially true for international approaches.

## Major Benefits

The MONERIS model approach can easily be transferred to other regions and river catchments and delivers standardized outputs important for reporting on the WFD. Thus, a standardized reporting approach with comparable outputs could be established through using this service on a regional scale and aggregating to national or international scale. The usage of catchment areas as the regional entities instead of legislative borders leads to easy integration into WFD reporting schemes required from the European Commission. Also the integration of all important pathways into the modelling approach guarantees a holistic consideration of all possible nutrient inputs into river systems.

## AquaSAGE: Water Abstraction Pressure by Irrigation

### Products / Services Delivered Today

The service consists in the provision of GIS based information reporting on the water abstraction pressure by irrigation in homogeneous hydrographical units of a catchment. It is made up of two products:

- A land cover map displaying irrigated crops. The first version of this product is presently available. It has a high-resolution and covers sub-catchment sectors. The second version will be a low-resolution product covering the complete catchment. It will be appropriate for most application cases of AquaSAGE. It will be available in France by the completion of SAGE (2004),
- A map of the irrigated surfaces combined with a map of the irrigation volumes per hydrographical unit. The irrigation volumes are computed for the year of the land cover and for a quinquennial and a decennial dry year.

These products have been generated for two pilot areas (System Neste, France and Flumen Irrigation Unit, Spain). They are to be delivered to national (e.g. National Environmental Institute) and regional (e.g. District Environmental Agencies, Water Catchment Agencies and Water Suppliers) every one or two years.

### Methodology

The high-resolution land cover results from a supervised classification based on the NDVI (Normalised Difference Vegetation Index) or on spectral bands (red, near infrared and middle infrared) (Landsat, SPOT). The images are acquired at key dates of the crops development. Inserting the land cover into a GIS software allows to generate the map of irrigated surfaces per hydrographical unit. A low-resolution version of this map will be produced from MERIS images. It is destined to replace the high-resolution product due to the lower cost and higher availability of MERIS images.

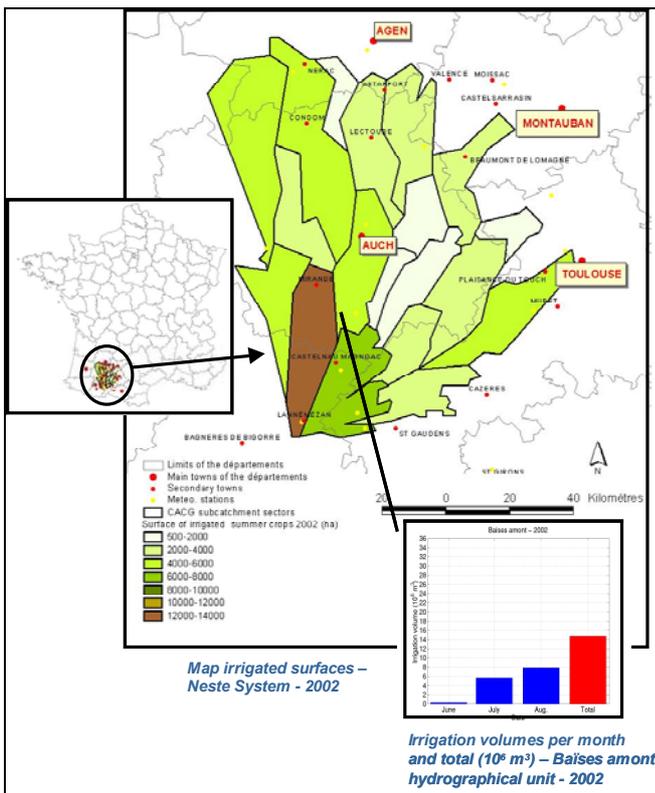
The irrigation heights per hydrographical unit are computed from a model taking into account the plant water demand according to the FAO (Food and Agriculture Organisation of UNO) method, the precipitations and the soil water content (for France) or irrigation efficiency (for Spain). The soil characteristics and the irrigation efficiency are measured from ground surveys or calibrated from the water volumes invoiced by the water suppliers. Multiplying the map of irrigated surfaces by the irrigation heights provides the map of irrigation volumes per hydrographical unit.

### Today's Constraints

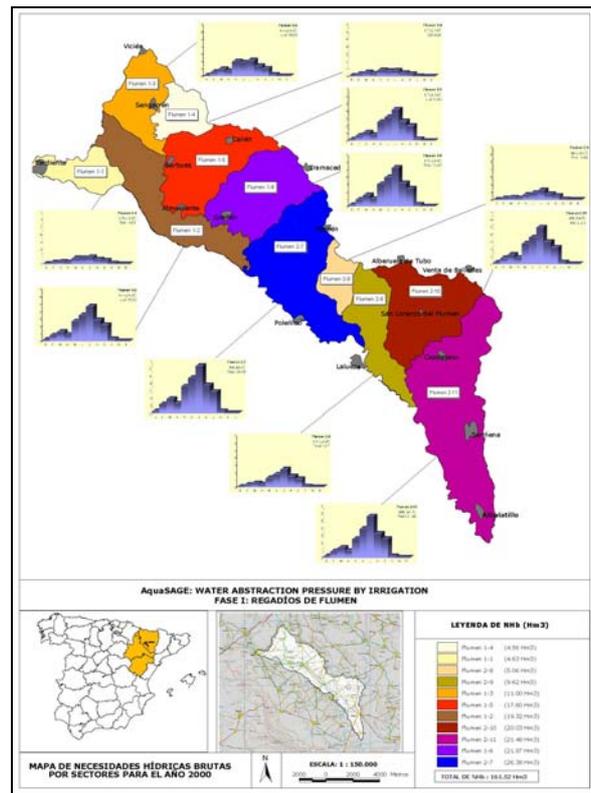
The main constraint on this service is the availability of complete and accurate databases on the soil properties. It also depends on the availability of satellite images. The use of the low-resolution sensor MERIS will restrict this constraint.

## Major Benefits

This service gives access to an accurate and reliable spatial distribution of the water abstraction pressure due to irrigation at the local and regional scale. It benefits to the water catchment authorities and water suppliers (irrigation, hydro-electricity) who have thereby a monitoring tool which provides the means for a more rationale and efficient management of the water resources. This better management will then benefit to various water users, including farmers, industry (secured access to water) and to the public (better water quality and quantity).



Map of irrigated surfaces for the Neste system (France) for the year 2002. Highlight on the monthly and total irrigation volume for the Baïses amount hydrographical unit.



Map of irrigation volumes for the Flumen Irrigation Unit (Spain) for the year 2000

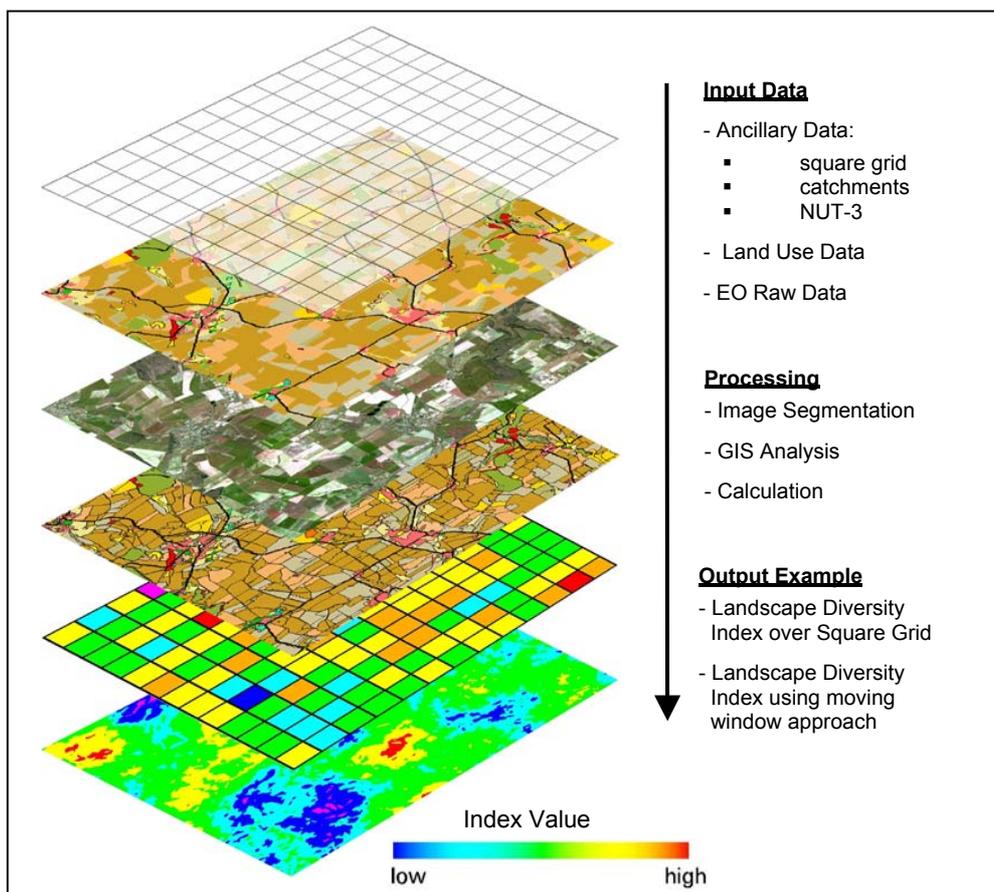
## Agri-environmental indicators

### Products / Services Delivered Today

To understand the development of environmental problems Environmental indicators are a key element. They can be useful to describe environmental changes and pressure. Communication is the main function of these indicators.

SAGE's environmental indicators are fitting into the core set of policy-relevant indicators EEA is just developing for six environmental issues (air pollution, climate change, water, waste and material flows, biodiversity and terrestrial environment) and five sectors (transport, energy, agriculture, tourism and fisheries). Within the GSE SAGE project environmental indicators primary the following environmental issues are addressed:

- Water
- Biodiversity
- Terrestrial environment
- Agriculture



*The image shows the workflow from complex input data (GIS-, EO and Land Use) towards condensed indicator information representing e.g. landscape diversity index over square grids and without delineation to a specific area using the moving window approach.*

Finally the service provides a set of indicators providing indicator maps and statistical data over catchments, NUTS 3 areas as well as 1 x 1 km grid cells. Additionally the technique of “moving windows” allows the production of results without delineation of raster cells or administrative units. It addresses primarily EU- and national environmental agencies, agriculture and landscape planning authorities, non-governmental environmental groups, planners, etc.

## Methodology

The products follow as far as applicable and reasonable the guide-lines and proposals of EEA and EUROSTAT and relevance is commonly assessed with reference to the Pressure/State/Response model (PSR) developed by OECD.

The basis for derivation of the selected environmental indicators are the CLC compatible generic land cover product (CSL-S-1) delivered from Infoterra and multi-temporal EO data. Using common of the shelf software (COTS) the indicators are derived via object-based image segmentation algorithms and GIS operations.

## Today's Constraints

Most spatial environmental indicators are based on CORINE Landcover (CLC) data. However, CLC is not the universal tool and, on many occasions, CLC data needs to be improved regarding accuracy and to be supplemented with other data on land cover and land use to provide a sound and relevant source for the production of useful information. The scale of CLC (1:100 000) and the size of the smallest mapping unit (25 ha) restrict the sensitivity of the tool. The updating over an average period of 10 years is also a limitation. Particularly in areas changing at a high pace or in areas under stress (e.g. coastal zones, urban zones, protected zones) it is necessary to have a more detailed inventory in order to capture changes of a smaller magnitude and, as well, to have more frequent updating.

## Major Benefits

Environmental indicators over large areas in a comprehensive and standardised way allow comparison between regions (i.e. catchments) with lower bias to detect non-natural changes. Because of this a quick reaction by policy makers and authorities on actual trends in the state of the environment (e.g. improvement versus degradation) is possible. The geometric resolution and the repeat rate of CORINE land cover (10 years) is too low for accuracy and actual indicators. Therefore, the benefit of SAGE indicators are to give information about changes of smaller magnitudes and to have more frequent updating. Additionally the indicators are designed as follows that they fit to the core set of policy-relevant indicators EEA is just developing for six environmental issues.

## Soil Sealing

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### Products / Services Delivered Today

The SoilSAGE products/services are maps and statistics related to land consumption and soil sealing and its change during the 1990ies. SoilSAGE is about to deliver this information to a national (e.g. Federal Environment Agencies) and several regional users (e.g. Landesregierung Vorarlberg). This has been done already for 1 pilot provinces in Austria at two scales (1:100.000 and 1:25.000), and two others will follow. The products are based on spaceborne EO data, aerial photography, maps, and other ancillary data, such as demographic and zoning data, etc. The EO component serves to derive land cover and soil sealing data, where the land cover component applies the CORINE LC nomenclature (level 1 and partly level 2/3).

A significantly improved LC (compared to CORINE in terms of minimum mapping unit 1ha and 0.25 ha, respectively) delivers a thematic accuracy of at least 95% for the artificial areas. The GIS component (including modelling approaches) of SoilSAGE co-analyses the EO derived results with ancillary data. The results describe and quantify the amount of land consumption in relation to demographic data, and assess the ecological and geophysical impact of soil sealing.

### Methodology

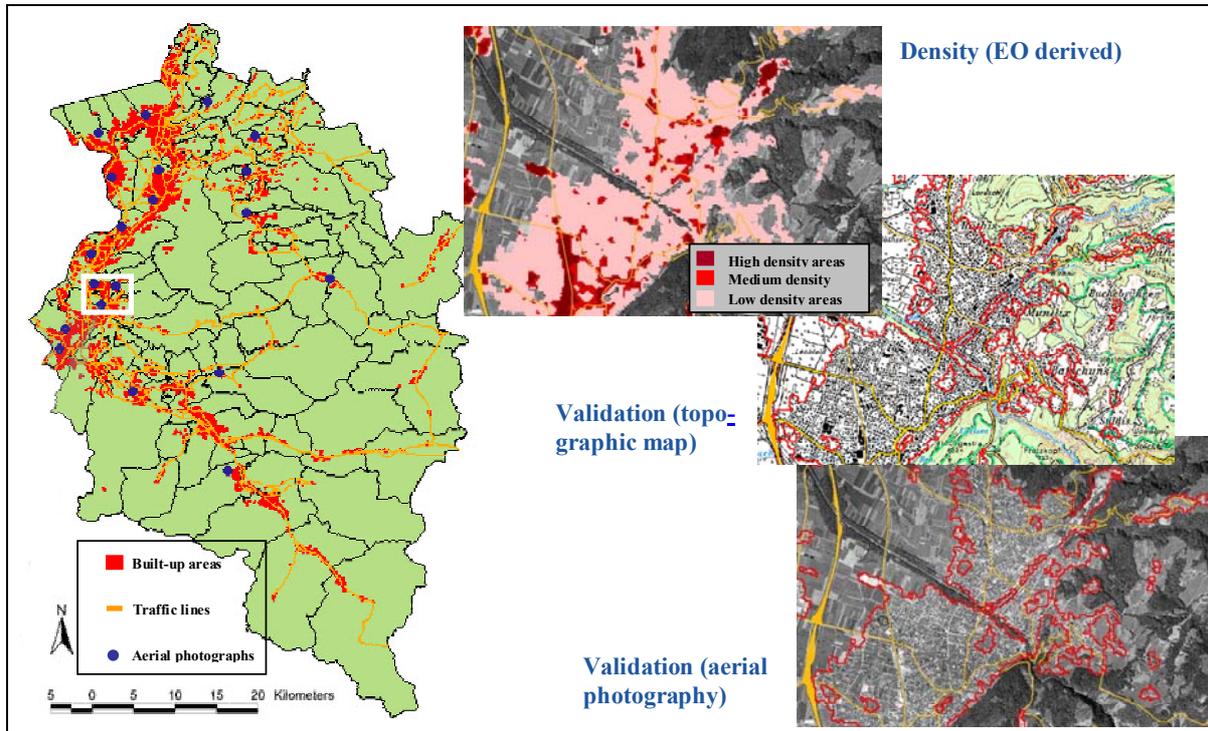
Besides standard geometrical pre-processing steps the EO methodology is composed of a sequence of methods of information extraction from the satellite data (SPOT, ERS, Landsat), i.e. automated image classification techniques, visual refinement of the classification results for correction and class refinement, and vegetation index based derivation of the degree of soil sealing. An intrinsic component of the methodology is the validation of the thematic results via aerial photography. Subsequently the LC products serve to generate secondary products via GIS analysis and models along with demographic and geo-spatial data, such as land use zoning data.

### Today's Constraints

Today's major constraints are EO data availability, missing thematic and geometric standards of the products, and the new characteristics of the provided information. Many users are not familiar with satellite derived products or may not accept them due to their lower geometric precision than that of aerial photography and cadastral or land use zoning based information (with lower thematic accuracy) they are currently using.

### Major Benefits

Major benefits arise from the consistency, timeliness, the spatial coverage, and from the localised nature of EO derived information on land consumption as opposed to the aggregated nature of the existent information. The latter allows for a spatial co-analysis of EO data and other geospatial data, which in turn enables localised impact assessment of land consumption and soil sealing as needed in many applications of spatial planning.



*Intermediate Soil Sealing Product (1:100.000), Province of Vorarlberg, Austria (2000)*

## AquaSAGE AND SoISAGE SERVICES IN THE NEXT 2 TO 5 YEARS

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SAGE will be based on existing European service networks to assure harmonised reporting to European bodies (e.g. EEA, DG ENV) and to support in addition national up to regional requirements from member states. The fragmented and money strapped service provider scene (represented here by the SAGE team and comparable partnerships established by Infoterra) is ready to build a strong Open Service Partnership within the GMES service implementation process driven by EC, ESA and member states.

The Open Service Concept envisaged will assure that the key issues for SAGE's success can be addressed; i.e.:

- **Reliability:** by establishing user-accepted standards for thematic content and accuracy and service providers committed to a GMES approved quality production process. This implies regulatory frameworks, like the Reporting Directive and accepted EO based products.
- **Affordability:** by emphasising centralisation where necessary and appropriate in order to achieve a standardized approach and by establishing flexible, modular production and delivery chains. This way, a lot of image processing and interpretation work can be carried out more effectively (i.e. faster, cheaper and much more standardised) and harmonised than with current project based approaches. However, it is recognised as well that any centralised data analysis approach has to stop at a certain stage, in order to address specific national, regional, ecological, or socio-economical conditions effectively. This is reflected in SAGE by late customising along the processing chain (i.e. from core services towards final products).
- **Availability:** by integrated value chains with open interfaces (w.r.t. INSPIRE, OGC, Reporting Directive) and multi-mission / multi-sensor approaches to allow for continuous data streams and maximal flexibility.
- **Sustainability:** by networking and production at European level to assure continuous work load and economic feasibility through serving several markets and market segments.

The schedule for the service roll-out permits flexible up-scaling from single projects via partner networks (allowing the specialisation of partners) up to centralised core services linked to specialised value adders in a maturing market.

The pre-condition of approved and sustainable GMES services for land applications will be assured via open data access to multi-mission EO data. Of similar importance is the open market access which allows all stake holders to step in or out at any time under commercial conditions.

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