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Definition and Analysis of New Agricultural Farm Energetic Indicators using Spatial OLAP

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Abstract. Agricultural energy consumption is an important environmental and social issue. Several diagnoses have been proposed to define indicators for analyzing energy consumption at large scale of agricultural farm activities (year, farm, family of production, etc.). However, to define ad-hoc environmental energetic policies to better monitor and control energy consumption, new indicators at a most detailed scale are needed. Moreover, by defining detailed scale indicators, large quantities of geo-referenced data need to be collected to feed these energetic diagnoses. This huge volume of data represents another important limitation of systems that implement these diagnoses because they are usually based on classical data storage systems (such as spreadsheet tools and Database Management Systems). These systems do not allow for interactive analysis at different granularities/scales of huge volumes of data and do not provide any cartographic representation. By contrast, Spatial OLAP (SOLAP) and spatial data warehouse (SDW) systems allow for the analysis of huge volumes of geo-referenced data by providing aggregated numerical values visualized by means of interactive tabular, graphical and cartographic displays. Thus, in this paper, we (i) propose new appropriate indicators to analyze agricultural farm energy performance at a detailed scale and (ii) show how SDW and SOLAP technologies can be used to represent, store and analyze these indicators by simultaneously producing expressive reports.

Keywords: Spatial Data Warehouses, Spatial OLAP, Energetic indicators

1 Introduction

Agriculture energy consumption depends on the method of production used. Direct agricultural energy consumption was estimated to be 28 Mtpe of a total consumption of 1142 Mtpe, which was 2.5% of the energy directly consumed by the EU25 in 2004 [17]; 55% of this energy was the result of fuel consumption. With the planned reduction in oil and rising oil prices, agriculture must reduce energy consumption to improve its economic development and decrease its environmental impact. Awareness of the importance of preserving non-renewable energy resources is a certainty, as evidenced by the energy development policies adopted in recent years by different governments (Energy Policy of 2005, the Grenelle Environment, etc.). Applied to the

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agricultural context, this reality requires a better assessment of the energy balance of farms in terms of energy performance. At present, many diagnoses that define a set of indicators exist to assess the energy performance of agricultural farms [13]. These diagnoses, which are specially adapted to a comprehensive assessment at the farm scale, are not necessarily relevant to evaluate the energy performance at a detailed scale (plot, technical operation, etc.). Moreover, by defining detailed scale indicators, large quantities of geo-referenced data have been collected to feed these energy diagnoses. This huge volume of data represents another important limitation of systems that implement these diagnoses because they are usually based on classical data storage systems, such as spreadsheet tools, which do not allow interactive analysis at different granularities/scales of huge volumes of geographic data. Moreover, diagnosis systems do not provide any cartographic visualization of energy indicators by limiting important analysis capabilities associated with geographic data [9].

By contrast, Geo-Business Intelligence technologies such as Spatial Data Warehouses (SDW) and Spatial OLAP (SOLAP) systems are widely recognized as efficient tools for the on-line analysis of huge volumes of geo-referenced datasets. SOLAP systems have been defined by Y. Bédard as "*Visual platforms built especially to support rapid and easy spatiotemporal analysis and exploration of data following a multidimensional approach comprised of aggregation levels available in cartographic displays as well as in tabular and diagram displays*" [3]. In the last years, SOLAP technology has been successfully used in several application domains such as geomarketing, health monitoring, and agriculture [11].

Thus, in this paper we propose (i) *some new appropriate indicators to analyze agricultural farm energy performance at a most detailed scale* and (ii) *show how SDW and SOLAP technologies can be used to represent, store and analyze these indicators by simultaneously producing cartographic and tabular reports*.

The case study of this work is a result of the EnergeTIC project. This project aims to use a scientific and technical solution to assess the energetic performance of farms through the use of ICT (Information and Communication Technologies) on the finest scale. Installed on agricultural equipment, the identified technological solutions (low-cost sensors, RFID, etc. provide reliable and continuous data to calculate energetic performance indicators at the finest scale (field, technical operation…).

The paper is organized as follows. Section 2 presents related work concerning agricultural energy diagnoses, SDW and SOLAP. New indicators for farm energy consumption at a detailed scale are presented in Section 3. Section 4 describes how the SDW system is used to represent these new indicators and their implementation in the SOLAP tool JMap-SOLAP. Conclusions and future work are presented in Section 5.

2 Related work

In this section, we introduce the main concepts of Spatial OLAP and the Spatial data warehouse (Sec. 2.2), and provide a survey of agricultural farm energy consumption diagnoses (Sec. 2.1).

2.1 Agricultural farm energy consumption diagnosis and related indicators

In the last few years, several studies dealing with direct and indirect energy consumption at the farm scale have been proposed [2][12][19]. These works aim to create complete diagnosis tools and/or energy performance assessment methods. The term "diagnosis" will be used in this paper to refer to both "tool" and "method". These diagnoses, based on the energy consumption of farms and the energy value of agricultural products, allow for the calculation of energy balance and the assessment of the energy efficiency of farms.

In particular, the energy diagnosis aims to:

- quantify energy consumption per processes to identify possible improvements by acting either on the production system, practices or equipment
- compare energy performance of livestock and crop farming, and
- establish reference values for the above production.

These diagnoses are based on the calculation of energy indicators, which are variables that provide information on less accessible data. These indicators are references used to make decisions [8], as they allow for the understanding of a complex system to assist in the realization of objectives [10].

We performed a survey of farm energy performance diagnoses used in France (Table 1). These diagnoses can be grouped into 6 categories (some examples of indicators are also provided):

- *Global agro-environmental diagnoses*: these consider the farm as a whole and assess the global environmental impact of the farm (nitrogen excess, energy consumption, etc.) (*Sum of the quantities of direct and indirect energy used by the farm, expressed in MJ per year*)
- *Field agro-environmental diagnoses*: these assess the environmental performance of the farm at the field scale (*Sum of the quantities of direct and indirect energy used by the farm, expressed in MJ per hectare per year*)
- *Sustainability diagnoses*: these assess farm sustainability performance through environmental, social and economic sustainability issues
- *Energetic diagnoses:* these allow an energy balance at the farm scale by quantifying energy inputs and outputs (*Energy efficiency: ∑(energy produced) / ∑(direct and indirect energy consumed)*)
- *Prediagnoses or autodiagnoses*: these assess the energy consumption of farm equipment and give an idea of the main possible improvements (based on the farmer’s qualitative assumptions)
- *Life cycle assessment*: these methods assess the environmental impact on a system by inventory pollutant emissions, raw materials and energy during its whole life cycle (*Energy consumption based on the functional unit used, either the hectare or milk liter*)

The main inputs of these diagnoses are direct and indirect energy flows and energy consuming operations (energy used for irrigation, for example). Direct energy flows are electricity, fuels and gases (propane, butane and city gas). Indirect energies are energies used to produce outputs such as fertilizers, crop protection products, etc.

Diagnosis	Scale	Category
PLANÈTE	Farm	Energy diagnoses
IDEA	Farm	Sustainability diagnoses
DIALECTE	Farm	Global agro-environmental diagnoses
DIALOGUE	Field Farm	Global/field agro-environmental diagnoses
INDIGO	Field Farm	Field agro-environmental diagnoses
BILAN CARBONE	Economic activity	Life cycle assessment
AUTO DIAGNOSTIC ÉNERGÉTIQUE DES BATIMENTS D'ÉLEVAGE	Farm	Auto diagnosis
GESTIM	Farm Operation	Energy diagnoses
AUDIT ÉNERGÉTIQUE EN PRODUCTION LAITIÈRE	Farm	Auto diagnosis
KUL	Farm	Global agro-environmental diagnoses
SALCA	Farm	Life cycle assessment

Table 1. Farm energy consumption diagnoses

The most common indicators are simple or aggregated indicators. For example, a simple indicator is the fuel quantity and two aggregated indicators are the energy balance and energy efficiency of farms. The calculation of these quantities is based on direct and indirect energy data collected from accountancy, paper documents or direct communication between farmers (equipment and building characteristics, produced quantities, etc.). Indeed, to the best of our knowledge, there is actually no technical solution implementation to collect farm energy data at this fine scale

Information obtained from these diagnoses allows for a good analysis of the global farm energy performance by identifying the most energy-consuming activities. As shown in Table 1, indicator calculation is most often limited to the global scale (i.e., farm scale) due to the lack of reliable data. An analysis at a most detailed scale (field, production activity or operation) will require more precise data acquisition systems.

This means that a set of new indicators at a most detailed scale is needed. Moreover, because collecting data at a fine scale produces a huge volume of data, classical systems used to analyze these indicators (e.g., spreadsheet tools and database management systems) are not sufficient in this context because they do not allow visual/cartographic interactive analysis at different granularities/scales of huge data volumes.

2.2 Spatial OLAP main concepts

A data warehouse is defined as "*a collection of historical, integrated uniformed collection of data to support decision making*" [15]. Warehoused data are organized according to the multidimensional model, which defines analysis axes, named dimensions, and analysis subjects (facts). Facts are described by numerical indicators (measures) and are analyzed along dimensions at different granularities or scales defined by hierarchical structures that compose the dimensions. A measure, when “observed” at coarser hierarchical levels, is aggregated using classical SQL aggregation functions such as SUM, MIN, MAX, etc. Multidimensional data are analyzed using OLAP tools, which provide operators to interactively analyze and explore data. These tools include Slice, which selects a part of the data warehouse; Dice, which projects one dimension; Roll-Up, which allows climbing into hierarchy-aggregating measures; and Drill-Down, which is the inverse of Roll-Up. OLAP tools, contrary to classical DBMS systems, are effective decision support systems, as they allow decision-makers to explore large quantities of data online by triggering OLAP operators with simple interaction through visual interfaces to produce graphical and tabular reports.

Introduction of spatial data in dimensions and facts leads to the concepts Spatial Data Warehouses (SDWs) and Spatial OLAP (SOLAP). SOLAP tools integrate OLAP and Geographic Information Systems (GIS) advanced functionalities to explore, visualize and analyze multidimensional geo-referenced data by means of tabular, graphic and interactive cartographic visualization [3]. In this way, spatial decision makers can visually detect unknown patterns and spatial phenomena and verify and/or formulate hypotheses. An example of the use of SDW to analyze pollution by French departments is presented in [4]. Here dimensions include (i) the temporal dimension organized into a classical calendar hierarchy (day, month, year), (ii) a dimension representing pollutants and (iii) a spatial dimension representing the French administrative organization into departments and regions. The measure is the pollution value that is aggregated using the average. Using this SDW, users can answer questions like: “*What was the average pollution value per pollutant and department in 2000?*” or “*What is the average pollution value per month per region for inorganic pollutants?*”.

A typical SOLAP architecture is composed of a Spatial DBMS to store warehoused (spatial) data; a SOLAP server, which implements OLAP operators; and a SOLAP client, which combines and synchronizes tabular, graphical and interactive maps to visualize and trigger SOLAP queries. An example of SOLAP visualization is shown in Figure 1 using the environmental SOLAP application previously described.

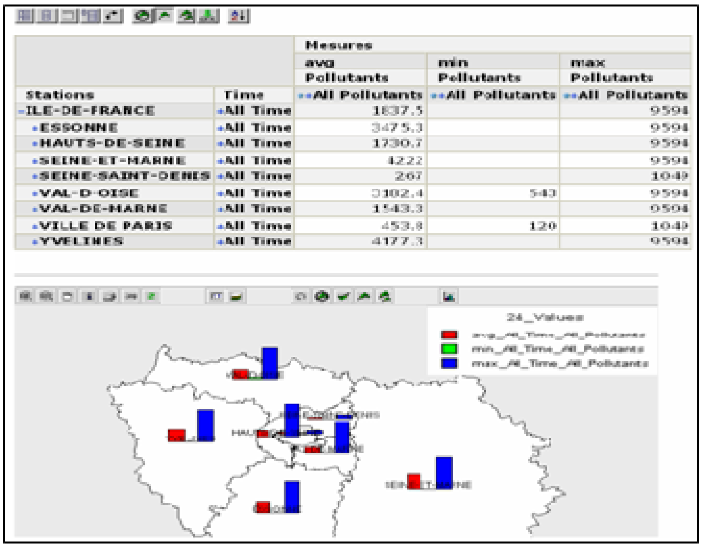

Fig. 1. SOLAP application concerning the monitoring of pollutants [4]

There are various SOLAP application domains, such as health, urban monitoring and marketing. Recently, SOLAP has also been applied to the agricultural context [18]. The monitoring of pollutants has been investigated in [1][4]. Economic analysis of agriculture productions is presented in [6][7][11][14][16]. These works highlight the relevance of using spatial decision support tools such as SDW and SOLAP in the agricultural context, and include evidence for particular issues concerning design of dimensions (complex hierarchies), facts (measures at different granularities, measure types, etc.) and architectural solutions (integration of GIS and Spatial Data Mining, etc.). However, to the best of our knowledge no works have studied the use of SDW and SOLAP systems to produce, aggregate and visualize energy consumption indicators of agricultural farms.

3 New energy indicators to assess farm performance at a detailed scale

The assessment of energy performance of farms at a detailed scale aims to establish what types of indicators are needed and the related assessment scale. We choose to design two types of indicators (Table 2):

- Indicators based on invoices, direct communication between farmers or administrative documents to assess indirect energy consumption (foodstuffs, fertilizers, pesticides, etc.).
- Indicators based on direct measurements collected by means of technological solutions installed on mobile equipment to assess direct energy consumption.

The indicators were designed according to the most relevant analysis scale:

- Spatial scale: the hectare is the spatial reference unit used to express the technical-economic results on a farm. We will use it to express all the direct energy flows, such as fuel or gas for mobile equipment, or to express indirect energy flows such as inputs in crop management (e.g., fertilizers, pesticides).
- Temporal scale: the hour is the temporal reference unit for farmers. This unit is frequently used to express fuel consumption for mobile equipment and electric/gas consumption for electric equipment.
- Production scale: all of the energy flows involved in farm activities (crop or cattle management) can also be expressed at the production scale. The results will be expressed with the common production unit used by the farmer depending on the type of farm production (e.g., tons of dry matter, liters of milk, etc.).

These indicators were calculated for the three main farm activities:

- Crop management activities, which include all the technical operations on crops (sowing, plowing, fertilization, harvest, etc.);
- Cattle management activities, which include all the technical operations on cattle, such as care, feeding and milk/meat production (milking, slaughtering, etc.);
- General activities, which cannot be allocated to cattle or crop management (cleaning, logistics, transport, etc.).

These indicators can be aggregated at the global scale using the sum.

An example indicator is the fuel consumption per plot, technical operation, year and production. An example of the value of this indicator is “140 liters of fuel used for the parcel ‘13 pal’ of the farm of Montoldre in 2010 during the plowing operation for the production of wheat”. An example of the aggregated indicator obtained from the previous indicator by aggregation on the spatial scale is the fuel consumption per department, technical operation, year and production. The aggregates are calculated by summing all the plots' values belonging to the same department (i.e., Allier).

4 Spatial OLAP analysis of new indicators

In this section, we propose a system to implement (represent, store and analyze) the indicators defined in Section 3. The main idea is to represent detailed indicators defined in Section 3 as measures of a spatial data warehouse and to represent their inputs (energy, time, spatial scale, technical operation and production) as dimensions. Thus, aggregated indicators correspond to aggregated measures.

In this way, the spatial data warehouse can provide answers to the questions of two types of users: farm managers and life-cycle assessment (LCA) practitioners. From the perspective of farm managers, useful SOLAP (i.e. (aggregated) indicators) queries are the "*number of interventions by culture*", etc. For LCA practitioners, questions arise in terms of life cycle assessment inventories. For example, it may be interesting to know the "*fuel to weed a plot of wheat*" and the "*average consumption of fuel to weed the entire farm per year*".

Energy flow			Indicator	Example	Indicator objective
Direct energy	Spatial scale	Fuels	FU[1]/crop ha/plot/technical operation	Energy consumption to weed 1 ha of wheat for plot X	Assess the most energy consuming operations for each technical operation for each crop Compare the energy consumption of the same operation for different crops
		Fuels, gas, renewable energies	FU/m²/type of building	Energy consumption to heat 1 m^2 of the milking parlor using electricity	Assess the most energy consuming buildings
	Temporal scale	Fuels, butane, propane gas	FU/hour/technical operation/equipment/crop	Energy consumption for 1 hour of weeding wheat with the XY equipment	Identify the most energy consuming equipment for each technical operation for each crop system
Indirect energy	Spatial scale	All inputs	FU/crop ha/technical operation	Energy consumption to weed 1 ha of wheat	Assess the most energy consuming operations for each technical operation for each crop
		Cleaning products	FU/m^2/building	Energy consumption to clean 1 m^2 of the milking parlor	Assess the most energy consuming buildings
	Temporal scale	All inputs	FU/year/production cycle/technical operation/crop	Annual (or production cycle) consumption to weed wheat	Identify the most energy consuming operations for each technical operation

Table 2. New indicators to assess farm performance at a detailed scale

Using a SOLAP system to represent indicators overcomes the limits of existing diagnosis systems with respect to two aspects: it allows the interactive analysis of huge volumes of (aggregated) indicator values and it provides a cartographic representation.

Figure 2 presents the conceptual schema of the spatial data warehouse we propose, using the multidimensional conceptual model based on the UML presented in [5]. The conceptual model presents stereotypes for each spatio-multidimensional element, such as "Fact" for the facts, "SpatialAggLevel" for spatial dimension levels (i.e., levels

[1] FU = Evaluated Flow unit (litre, kWh, kg…)

having a geometric attribute "LevelGeometry" that represents the locations of their members), "AggRelationship" for hierarchical associations between dimension levels, "DimRelationship "for associations between levels and facts, etc.

The SDW presents several measures that represent the previous indicators defined in Section 3. In particular, the measures are: the area worked (*surface_w*), the number of animals (*animaux_nb*), the amount of product (input represented with “*intrant*” and output denoted with “*extrant*”) used during work or no work (denoted with “w” and “nw”, respectively), the duration in hours (*duree_w* and *dure_nw*) and the distance traveled (*distance_parcourue_w* and *distance_parcourue_nw*). The measures are aggregated using the sum on all dimensions.

The difference between work and no work (*w* and *nw*) is used to quantify energy consumption both directly related to and not attributable to work. For example, the amount of fuel used to plow a field is associated with work, while the amount consumed during the turn of the machine, with the plow raised, is not considered directly related to work.

The different dimensions are:

- Campaigns (*Campagne*): production cycles expressed in years (e.g., wheat produced in 2009)
- Time (*Temps*): classical temporal dimension, in which days are grouped by month and year.
- Products (*Produits*): the input and output products (intrant and extrant). Products are grouped recursively into larger classes of products
- Operators (Opérateurs): people who perform the operation
- Equipment (Attelage): machines and tools used
- Location: the spatial dimension that groups plots (parcelle) by farm (exploitation), department (département) and region (région)
- Productions: type of production (e.g. wheat)
- Technical Operations (Opérations Técniques): the technical operations performed, which are grouped by functions.

Using this spatio-multidimensional model, it is possible to represent and aggregate all indicators presented in section 3 such as the fuel consumption per plot, technical operation, year and production.

For the implementation of our application we have chosen the SOLAP tool JMap-SOLAP because it is one of the best business solutions that incorporates all existing OLAP and GIS functionalities. JMap-SOLAP is based on a three-tiers of Relational SOLAP architecture as described in Section 2.2. The SOLAP server allows the definition of the elements of the spatial data warehouse and the various data access policies for different users through a simple visual interface. The SOLAP web client integrates intelligent mapping concepts that support the automatic creation of thematic maps, while ensuring compliance with the semiotics rules (colors, symbols, frames, etc.). The client provides simple and multi-maps with synchronized diagrams and tabular displays to visualize SOLAP queries results. The client also implements the SOLAP operators described in Section 2.2.

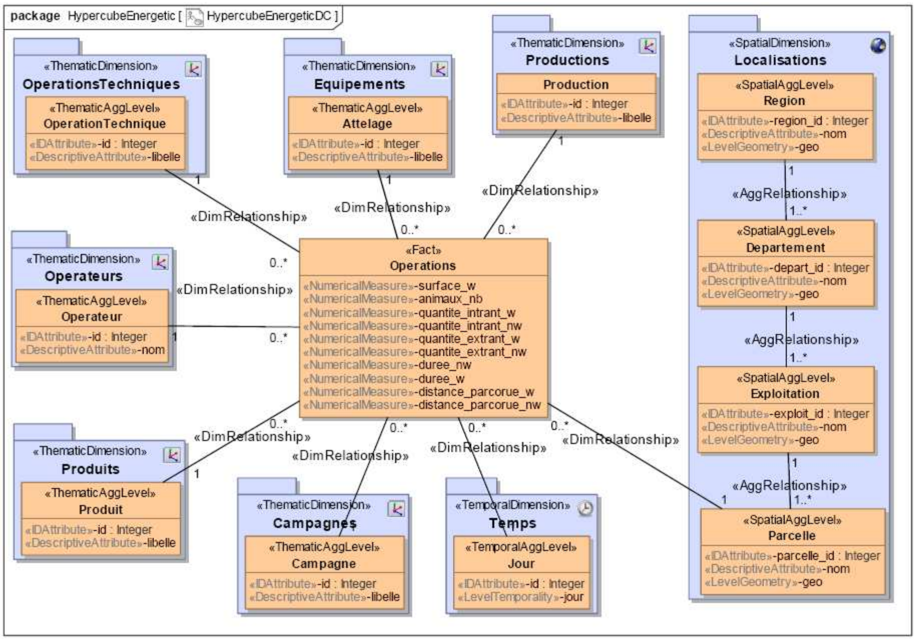

Fig. 2. SDW for indicators of Table 2

In the following figure we show how to formulate and visualize spatio-multidimensional queries to obtain, for example, the aggregated indicator "the amount of fuel used for cultivating one hectare of wheat on the Montoldre farm". Once the user has selected interesting items (e.g., dimension elements) for the indicator calculation, the table in Figure 3 is displayed showing the quantities of fuel consumed per hectare over the entire Montoldre farm. The result can also be displayed on a map (Figure 3).

The decision maker can apply a spatial drill-down operation directly on the map to obtain the energy consumption per plot. The result, shown in Figure 4, indicates that "PIQ 1" and "2PIQ" are the parcels that have consumed the most energy. It is also possible to determine the most expensive technical operations in terms of fuel. Using the operator to drill-down on the technical operations dimension of the previous table, a new table is shown (Figure 5), which gives more details on energy consumption by plot.

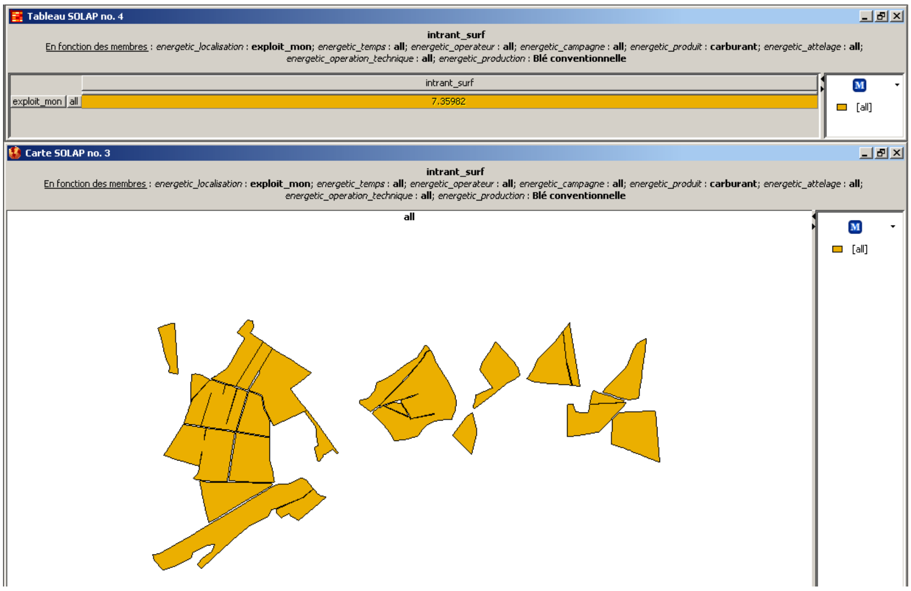

Fig. 3. Visualization of the aggregated indicator “the amount of fuel used for cultivating one hectare of wheat on the Montoldre farm”

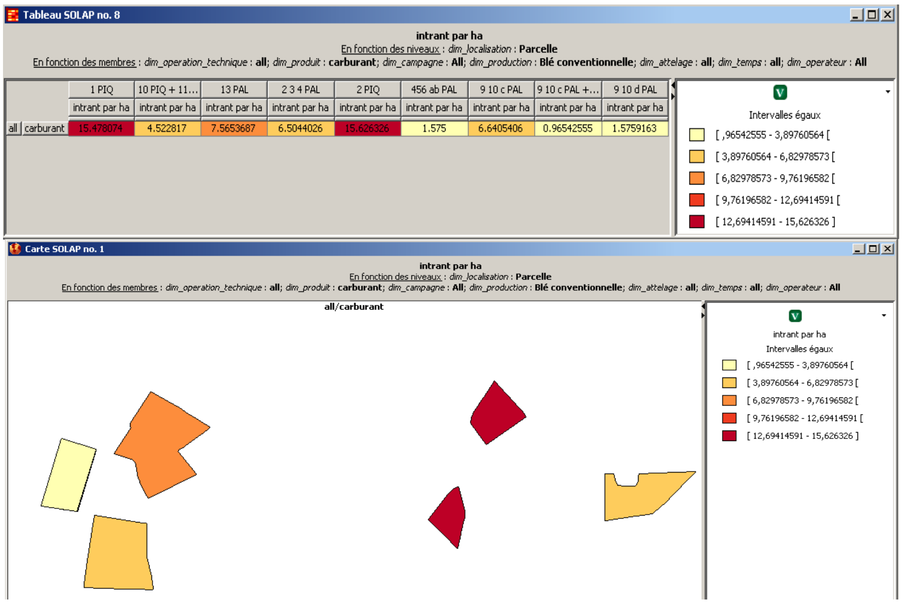

Fig. 4. Visualization of the indicator “the amount of fuel used for cultivating one hectare of wheat for each plot of the Montoldre farm”

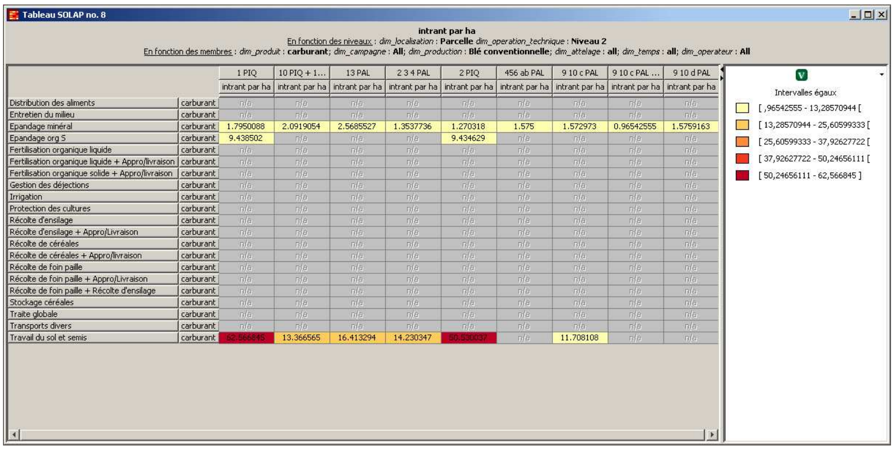

Tableau SOLAP no. 8

intrant par ha

En fonction des niveaux : *dim_localisation* : **Parcelle** *dim_operation_technique* : **Niveau 2**

En fonction des membres : *dim_produit* : **carburant**; *dim_campagne* : **All**; *dim_production* : **Blé conventionnelle**; *dim_attelage* : **all**; *dim_temps* : **all**; *dim_operateur* : **All**

		1 PIQ	10 PIQ + 1...	13 PAL	2 3 4 PAL	2 PIQ	456 ab PAL	9 10 c PAL	9 10 c PAL ...	9 10 d PAL
		intrant par ha	intrant par ha	intrant par ha	intrant par ha	intrant par ha	intrant par ha	intrant par ha	intrant par ha	intrant par ha
Distribution des aliments	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Entretien du milieu	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Epandage minéral	carburant	1.7950088	2.0919054	2.5685527	1.3537736	1.270318	1.575	1.572973	0.96542555	1.5759163
Epandage org S	carburant	9.438502	n/a	n/a	n/a	9.434629	n/a	n/a	n/a	n/a
Fertilisation organique liquide	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fertilisation organique liquide + Appro/livraison	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fertilisation organique solide + Appro/livraison	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gestion des déjections	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Irrigation	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Protection des cultures	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte d'ensilage	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte d'ensilage + Appro/Livraison	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte de céréales	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte de céréales + Appro/livraison	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte de foin paille	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte de foin paille + Appro/Livraison	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Récolte de foin paille + Récolte d'ensilage	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Stockage céréales	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Traite globale	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Transports divers	carburant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Travail du sol et semis	carburant	62.566845	13.366565	16.413294	14.230347	50.530037	n/a	11.708108	n/a	n/a

Fig. 5. Visualization of the indicator "the amount of fuel used for cultivating one hectare of wheat for each technical operation for each plot of the Montoldre farm"

In the same way, the example of the indicator described in Section 3, "fuel consumption per plot, technical operation, year and production", can be easily visualized in our system by using the SOLAP query, the result of which is shown in Figure 6.

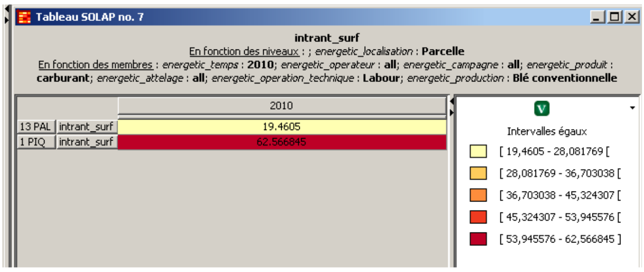

Tableau SOLAP no. 7

intrant_surf

En fonction des niveaux : ; *energetic_localisation* : **Parcelle**

En fonction des membres : *energetic_temps* : **2010**; *energetic_operateur* : **all**; *energetic_campagne* : **all**; *energetic_produit* : **carburant**; *energetic_attelage* : **all**; *energetic_operation_technique* : **Labour**; *energetic_production* : **Blé conventionnelle**

		2010
13 PAL	intrant_surf	19.4605
1 PIQ	intrant_surf	62.566845

Fig. 6. Visualization of the indicator "fuel consumption per plot, technical operation, year and production"

5 Conclusions

Quantifying the impacts of human activities has now become an important issue for society, including agriculture. This quantification may eventually reduce these impacts by changing the most polluting practices, which is the reason several diagnoses defining a set of indicators exist to assess the energy performance of agricultural farms. However, these diagnoses present two important limitations: 1) they define indicators only at a global scale, avoiding the finest analysis of energy consumption related to technical operations, and 2) they are based on classical data storage systems that do not allow interactive cartographic analysis of huge volumes of data.

By contrast, SDW and SOLAP technologies provide tools to interactively analyze massive geo-referenced data sets. Recently, SOLAP has been successfully applied in the agriculture domain. Thus, to overcome the previously described limits, in this paper, we propose some new indicators to assess agricultural farm performance at a most detailed scale. We also show how it is possible to represent these indicators using a spatial data warehouse and analyze them by means of a classical SOLAP system.

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