AgriBigCAT: An Online Platform for Estimating the Impact of Livestock Agriculture on the Environment

Andreas Kamilaris[1]**, Anton Assumpcio, August Bonmati Blasi**, and **Francesc X. Prenafeta-Boldú**

GIRO Joint Research Unit IRTA-UPC, Barcelona, Spain

Keywords: Environmental impact, Livestock Agriculture, GIS, Big Data Analysis, Manure Management.

Abstract: Intensive farming has been linked to excessive accumulation of heavy metals and other contaminants on soil, and to significant groundwater pollution with nitrates. Hence, it is necessary to develop a common body of knowledge, so as to allow an effective monitoring of cropping systems, fertilization and water demands, and impacts of climate change, with a focus on the sustainability and the protection of the physical environment. In this paper, we describe AgriBigCAT, an online software platform that uses geophysical information from various diverse sources, employing geospatial and big data analysis, together with web technologies, in order to estimate the impact of the agricultural sector on the environment. It considers land, water, biodiversity and natural areas requiring protection, such as forests and wetlands. This platform can assist both the farmers' decision-taking processes and the administration planning and policymaking, with the ultimate objective of meeting the challenge of increasing food production at a lower environmental impact. An online application of AgriBigCAT, focusing on the local environmental issues of the agricultural sector of Catalonia, is presented and described, together with some preliminary analysis findings.

1. Introduction

The agricultural sector plays a central role in the policies of all countries around the world because of its economic, social and environmental relevance. Because of insufficient accessible arable land, intensive farming has been linked to excessive accumulation of phosphorous, heavy metals, and other soil contaminants, as well as to significant groundwater pollution with nitrate. Deterioration of soil water quality is especially worrying at the bioclimatic Mediterranean area, especially under the current context of climate change. Hence, it is necessary to develop a common body of knowledge, shared at the local and regional levels of the countries involved and affected, so as to allow an effective monitoring of cropping systems, fertilization and water demands, and impacts of climate change, with a focus on the sustainability and the protection of the physical

[1] Corresponding Author. Email: andreas.kamilaris@irta.cat

environment. This knowledge shall be available as a tool to policy-makers and relevant stakeholders to assess the risks involved, take appropriate counter-measures and make more informed decisions.

To address this challenge, we have developed AgriBigCAT, an online software platform that combines web technologies together with geospatial analysis and big data analysis, to assess the impact of agriculture on the environment. In the next sections, we describe AgriBigCAT and its features, and some preliminary results.

2. AgriBigCAT Platform Description

AgriBigCAT (P-Sphere Project, 2017) is an online software platform that combines geophysical information from various diverse sources, together with big data analysis, in order to estimate the impact of the agricultural sector on the physical environment (e.g. land, water, biodiversity and natural areas requiring protection, such as forests and wetlands). Based on the P-Sphere project, this platform intends to promote a more sustainable agriculture, by designing and developing an information and knowledge-based platform, using a big data approach for managing and analyzing a wide range of geospatial and mainstream information, which can be accessible by standard communication technologies such as the Internet/web and mobile phone applications. The abstract architecture of AgriBigCAT is illustrated in Figure 1.

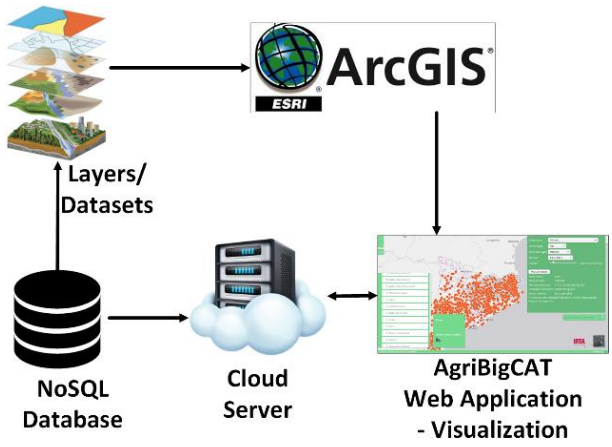

Figure 1: AgriBigCAT Architecture.

Our platform stores geophysical information and other relevant datasets using Apache Hive (Apache Hive, 2011), a (big) database software that facilitates reading, writing, and managing large datasets residing in distributed storage. Visualizations of the datasets as well as geospatial analysis are performed by means of the ArcGIS API for JavaScript (ESRI, 2017), which allows the platform to be developed by using open web technologies (e.g. HTML, CSS, JavaScript, AJAX, PHP), but at the same time use the visualization and geospatial features of ArcGIS through its JavaScript API. The platform allows data acquisition and analysis of relevant parameters in various agricultural systems, for promoting more precise management and use of inputs (e.g. energy, nutrients and water) and outputs (e.g. emissions, biomass yield, etc.). This platform can also be used for the simulation of nutrient balances under different scenarios, in order to assist both the farmers'

decision-taking processes and the administration planning and policy making, with the ultimate objective of meeting the challenge of increasing food production at a lower environmental impact.

3. Case Study: The Region of Catalonia

We have primarily focused in the area of Catalonia (Spain), motivated by the fact that it is one of the European regions with the highest livestock density, with farm concentrations of more than 6M pigs, 0.7M cows and 38M poultry (DARP, 2008). The high density of livestock in some particular areas, linked to the insufficient accessible arable land, has resulted in severe groundwater pollution with nitrate (EEC, 1991). Excessive soil accumulation of phosphorous and heavy metals from manure has also been reported in certain areas (Teira-Esmatges & Flotats, 2003). As a first step, we collected diverse information datasets of the territorial domain of Catalonia, as listed in Table 1.

No.	Area/Group	Datasets
1.	People, farm and animals	Manure management units, Farmers in Catalonia and numbers of animals and animal types they possess, Habitats of Catalonia, Crops.
2.	Areas of Catalonia	Controlled fishing, Evapotranspiration and thermal regions, Areas vulnerable in nitrates, Public forests, Areas of natural interest, Fishing areas, Municipalities, Land parcels, Soil.
3.	Infrastructure	Wind parks, Main and secondary road networks, Water pipelines network.
4.	Biodiversity	Vertebrates, Lormophytes, Lichens, Bryophytes, Waterbirds.
5.	Clime and atmosphere	Thermal levels, Temperature (annual and monthly), Rainfall (annual and monthly), Noise map, Clime type, Atmospheric emissions (C02).
6.	Water	Wetlands, Wastewater plants, Watersheds, Rivers, Reservoirs, Quality control points, Monitoring stations, Lakes, Water-deficit areas, Coasts, Bays, Aquifers.

Table 1: Datasets Used in the Catalonia Case Study.

These datasets are available through the AgriBigCAT platform as layers, for enabling different visualizations (P-Sphere Project, 2017), as depicted in Figure 2.

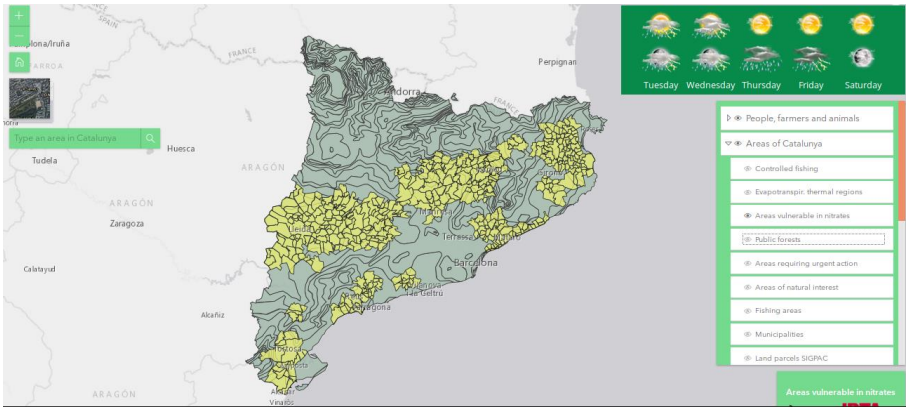

Figure 2: AgriBigCAT Layers Visualization.

Another interesting application developed on the AgriBigCAT platform is an online calculator of the impact of animal manure on the environment, in different areas of Catalonia (P-Sphere Project, 2017). A snapshot of this application is provided in Figure 3.

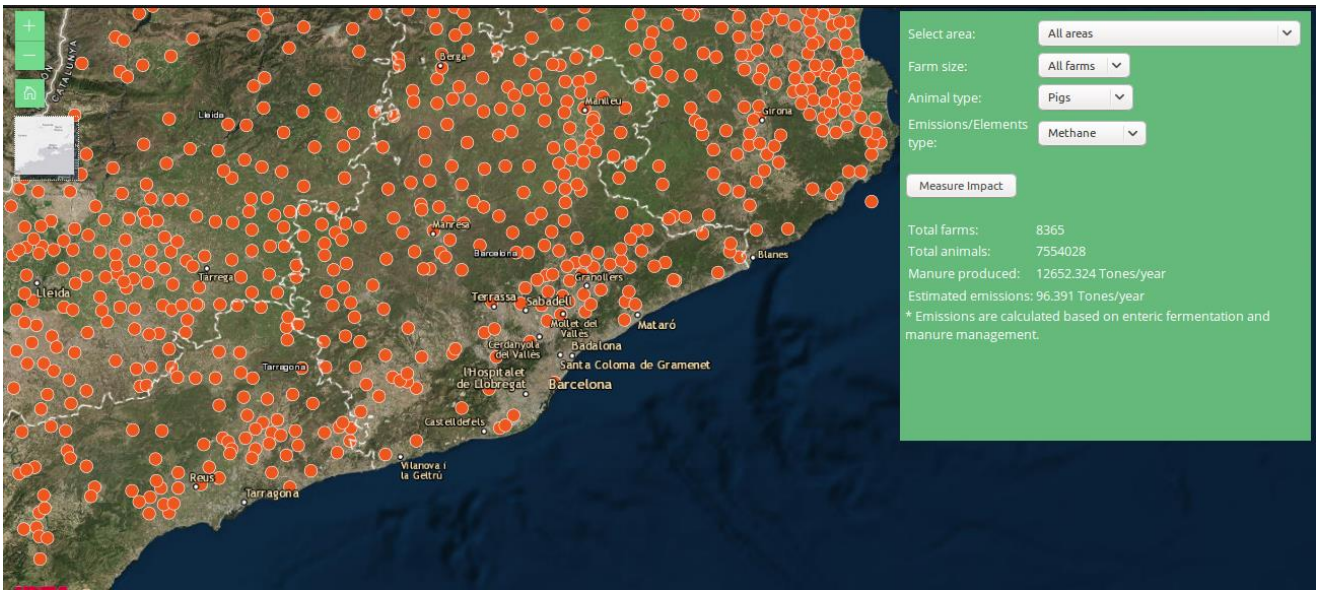

Figure 3: Online Calculator of the Impact of Agriculture in Different Areas of Catalonia.

As Figure 3 shows, in the top-right side, the user can select a particular area in Catalonia (or all areas), farm size (e.g. small, average, large, very large), particular animal type (e.g. pigs, dairy cows, poultry, beef cattle or all animals), and emission type (e.g. carbon dioxide, methane, nitrous oxide, ammonia, odour or phosphorous) and the application calculates the farms and animals involved in the query, manure produced and estimated emissions in monthly or yearly basis, taking into account the existing weather and thermal conditions at the selected time period, either from historical data (past periods) or from forecasting (future periods). Calculations are based on the IPCC guidelines (TIER1) or relevant literature (TIER2) (IPCC, 2006). In the above snapshot, the user examines the impact of the pigs' manure as methane emissions, around the whole of Catalonia.

Finally, various geospatial maps have been developed (P-Sphere Project, 2017), illustrating farms' and animals' density, manure produced around each municipality of Catalonia, as well as the greenhouse emissions and nitrogen/phosphorous produced yearly by the livestock industry in different areas. Figure 4 presents two snapshots that show this feature on the AgriBigCAT platform. At the left, the user can select from various different maps, either to view them, get relevant info about how they had been produced, or download the raw data in CSV format. At the right, a geospatial map showing the yearly ammonia emissions per municipality around Catalonia is provided, from blue (low emissions) to yellow (high emissions).

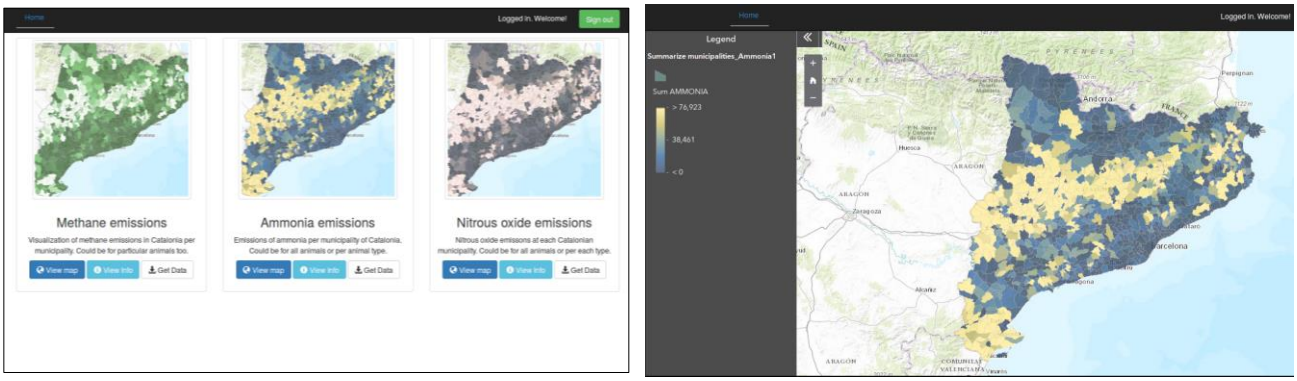

Figure 4: Geospatial Maps illustrating the Impact of Agriculture on the Environment. Snapshot of the different Emission Maps (left). Snapshot of the Ammonia Emissions (right).

4. Preliminary Results

As preliminary results, considering the application of AgriBigCAT in the region of Catalonia, we followed the IPCC guidelines for emissions from livestock and manure management (IPCC, 2006), in order to estimate the greenhouse gas emissions produced by the livestock industry in the area. Total tones of manure, methane emissions, ammonia emissions and emissions of nitrous oxide, produced by different types of animal are presented in Table 2, together with total numbers of farms and animals.

Animal Type	Total Farms	Total Animals	Manure Prod. (tones/year)	Methane Emis. (tones/year)	Ammonia Emis. (tones/year)	Nitrous Oxide (tones/year)
Pigs	8350	7 553 068	12 650	96.379	19.353	41.979
Dairy Cows	1772	201 393	2 243	30.646	3.403	4.527
Beef Cattle	5403	915 266	12 539	52.520	N/A	2.910
Chicken	1655	32 099 171	1 222	0.641	11.125	0.546
Sheep	3355	1 818 852	1 204	15.444	2.546	0.645
Turkey	162	1 334 997	103	0.116	1.268	0.057
TOTAL	**20,697**	**43 922 747**	**29 963**	**195.746**	**37.697**	**50.664**

Table 2: Methane Emissions.

From Table 2, it is evident that pig farms constitute the large majority in the area, followed by beef cattle farms. These two types of farms are largely responsible for the total yearly methane emissions (76%). Pig farms are largely responsible for total yearly ammonia emissions (51%) and nitrous oxide emissions (82%). These statistics, together with geospatial maps (see Section 3) providing geospatial information over the

distribution of farms, animals, manure produced and emissions around Catalonia, allow policy- and decision-makers to better understand the impact of livestock agriculture on the physical environment of the region. Combining with calculations of nitrates/phosphorous excreted, together with visualizations of land and water (e.g. areas vulnerable to pollution), soil and crop types and rainfall patterns (features available through AgriBigCAT), stakeholders could assess the yearly impact of the livestock industry with high precision.

5. Conclusion

This paper has described AgriBigCAT, an online software platform combining geospatial and big data analysis, together with web technologies, to estimate the impact of the agricultural sector on the environment. Serving as a knowledge-based platform, it constitutes a useful tool for administration planning and policy making, contributing to the challenge of increasing food production at a lower environmental impact. Moreover, an online application of AgriBigCAT, focusing on the local environmental issues of the agricultural sector of Catalonia, has been presented and described. As future work, we plan to increase the flexibility and adaptability of AgriBigCAT, to be easily used in different applications, such as the one of Catalonia presented in this paper. In parallel, we plan to release the source code of AgriBigCAT in GitHub, developing a content management system (CMS) that would allow users and web developers to publish their own content, including visualizations and geospatial maps. Finally, we will provide tutorials and user manuals assisting users and researchers to perform big data and geospatial analysis through GIS tools and online big databases, and then provide their results in web-based platforms similar to AgriBigCAT.

Acknowledgments

This research has been supported by the P-SPHERE project, which has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skodowska-Curie grant agreement No 665919.

References

Apache Hive (2011). Online at: https://hive.apache.org/

ESRI (2017). ArcGIS API for JavaScript. Online at: https://developers.arcgis.com/javascript/

DARP (2008). Departament d'Agricultura Alimentació i Acció Rural, Barcelona, Spain (in Catalan). Online at: http://www20.gencat.cat/portal/site/DAR/

EEC (1991). Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Off. J. 1991;L 375 [31/12/1991].

IPCC (2006). Chapter 10: Emissions from livestock and manure management, s.l.: IPCC Guidelines for National Greenhouse Gas Inventories.

P-Sphere Project (2017). AgriBigCAT Online Platform. Online at: http://www.psphere-project.com/

Teira-Esmatges, MR; Flotats, X (2003). A method for livestock waste management planning in NE Spain. Waste Management 23: 917-932