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Estimating pesticide use across the EU

Accessible data and gap-filling

Galimberti, F., Dorati, C., Udias, A., Pistocchi , A.

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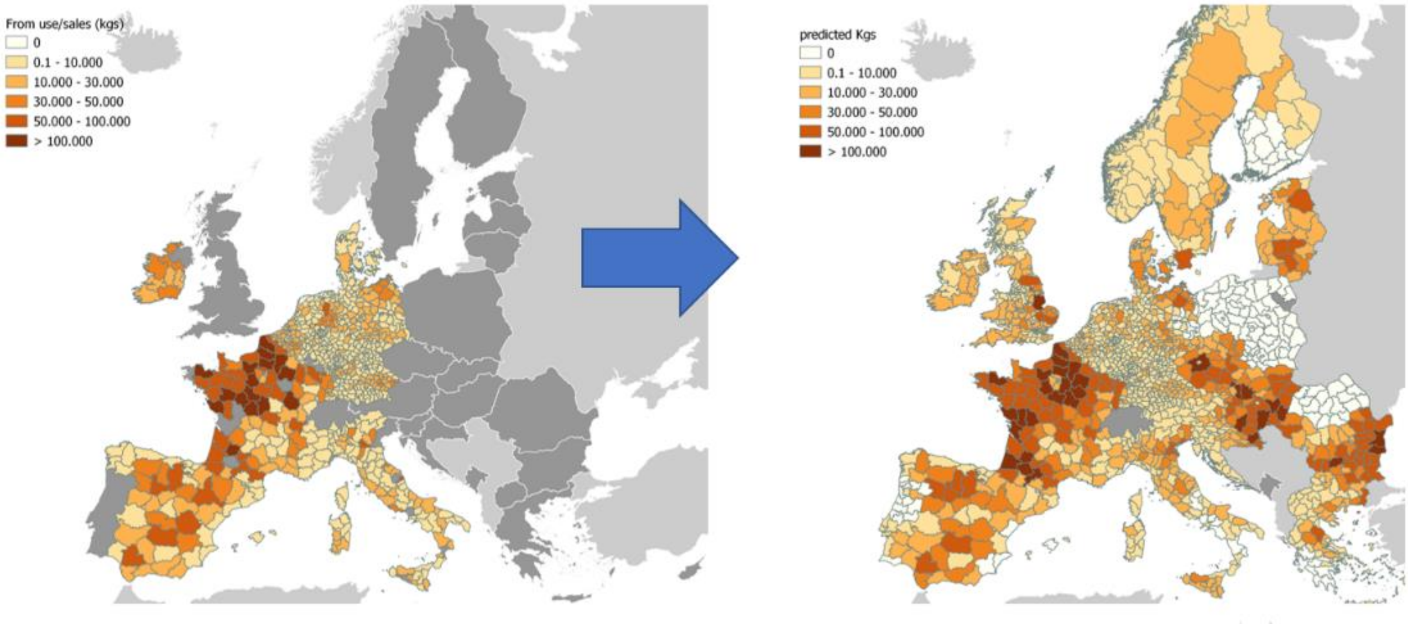

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Contents

Acknowledgements

The report describes the outcomes of a workshop on "Estimating pesticide use across the EU: accessible data and gap-filling", held in Brussels at the JRC Headquarters on 9-10 April 2019. Moreover, it presents the work done on the data gathered through collaboration with selected countries' experts, aimed at mapping pesticide use in those countries, as a basis for the generalization of the estimate to the rest of Europe. The workshop was attended by experts from Germany, France, Italy, Portugal, Denmark, Belgium, the Netherlands, Ireland, Slovakia and Poland. In addition, the ensuing data analysis work was extended to Spain and the United Kingdom, for which suitable data could be retrieved.

The following experts, participating to the workshop, are gratefully acknowledged:

Gottfried Besenhofer (Austria), Vincent van Bol (Belgium), Kirsten Martensen (Denmark), Christine Veyrac (France), Joern Strassemeyer (Germany), James Quirke (Ireland), Mariusz Wojciechowski (Poland), Miriam Cavaco (Portugal), Rob Vijftigschild (the Netherlands), Bronislava Skarbova (Slovakia).

Moreover, we would like to acknowledge Mr Israel Senra Diaz (Spain) for facilitating access to data for his country.

Colleagues Oihane Fernandez Ugalde (JRC), Ebba Barany and Susanne Mauren (EUROSTAT) and Dara O'Shea (DG SANTE) are gratefully acknowledged for their participation and contribution to the workshop. Finally, we wish to thank the IPCheM team in Directorate F of the JRC, for facilitating access to chemical monitoring data.

1 Introduction

Information on the use of pesticide active substances in the EU is needed to estimate their overall and cumulative impact on ecosystems and human health. The application of pesticides is strictly controlled by Community legislation since 1991. Policy control measures in the EU are driven by the objectives of protecting human health and the environment (consumers, operator safety, protection of water quality and biodiversity). In 2009, the Sustainable Use Directive (Directive 2009/128/EC) established a framework to achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment. The same year, Regulation (EC) 1185/2009 on pesticide statistics was adopted, covering collections of statistics on pesticide active substances' use and placing on the market (sales). The data on annual pesticides sales is available in EUROSTAT's public dissemination database. However, due to a lack of harmonization in the national surveys collecting pesticide use statistics, the use data cannot be aggregated and published at EU level.

For confidentiality reasons, the statistics presently available at EU-level (annual data on pesticide active substances placed on the market), are aggregated to pesticide major groups and categories of products, In many EU Member States, or regions thereof, detailed data may be publicly available for individual active substances. A theoretical model can be developed to estimate pesticide use in space and time, based on information on crops, climate and other territorial characteristics, but such a model requires calibration and validation based on data available in the public domain.

The objective of the workshop was to collect first-hand information from experts in different EU Member States on data publicly available in their country/regions on pesticide use or proxies, such as pesticide sales, for individual active substances, in order to identify options for the development of a pan-EU pesticide use model. The latter is a necessary input for the assessment of cumulative impacts of pesticides in the EU. Figure 1 shows the spatial distribution of data availability.

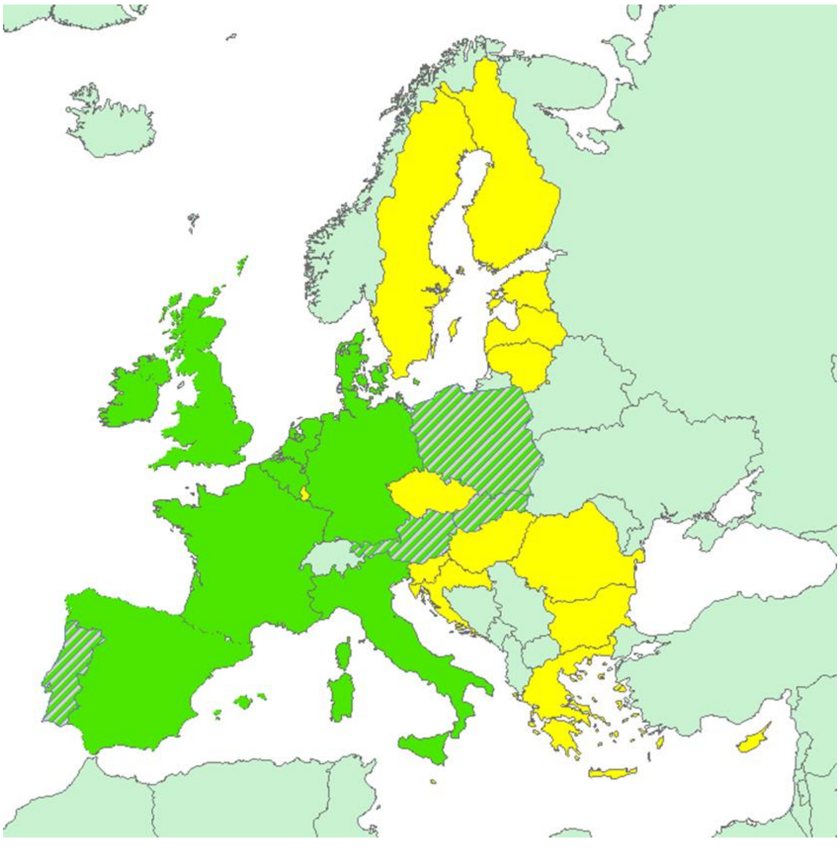


Figure 1 – countries for which data could be retrieved on the sale or use of individual active substances (green); countries with data existing but not available (dashed green) and other EU countries for which no information could be retrieved (yellow).

2 Data available to the Commission

During the workshop, Dara O'Shea from SANTE introduced the policy context of the Sustainable pesticide Use Directive (SUD) 2009/128/EC, and the current European harmonized pesticide risk indicators (Commission Directive (EU) 2019/782). The first of these indicators is a weighted sum of the sales quantities of active ingredients in Europe, with weights assigned on a conventional basis to reflect the different categories of risk of chemicals. The indicator delivers an aggregated metric of the hazard related to pesticide sales in Europe.

During the workshop, Ebba Barany from Eurostat presented the state of play of the collection and publication of pesticide statistics in the EU. Statistics on pesticide sales are readily available in Eurostat's dissemination database for the reference years 2011-2017. The pesticide use data collected so far under the pesticides statistics Regulation (EC) 1185/2009 suffers from a lack of harmonization of the reference periods surveyed, target crops and reference areas.

At present, the data on pesticide use collected by EUROSTAT are so heterogeneous that they cannot be used in themselves to draw any conclusion on pesticide use in the EU. During the workshop, Alberto Pistocchi from JRC proposed that they could still be used as "sampling point data" for the verification of a pesticide use model whose need is thus corroborated in order to quantify pesticide impact. However, it was ascertained that confidentiality constraints do not allow use of such data even for mere model verification.

3 Presentations by experts from different Member States

3.1 Austria

Mr Gottfried Besenhofer from the Austrian Agency for Health and Food Safety (AGES) presented the situation in Austria. In Austria the data on active substances are not publicly available, with the exception of a handful of active substances e.g. glyphosate, sulfur and copper. Only data on aggregated groups are publised annually. Similarly, for data on the use of plant protection products, only results for the main groups of pesticides for individual crops are published.

3.2 Belgium

Mr Vincent van Bol of the Belgian federal Ministry of public health presented the situation of pesticide data in Belgium. Use data for active ingredients are available but belong to the Regions; use is estimated from a sample of farms and extrapolated to national/regional totals. In BE, all sales data by active ingredient are available, with data masked out for the 3 most recent years before reporting due to confidentiality reasons.

3.3 Denmark

Ms Kirsten Martensen of the Danish Environmental Protection Agency presented sales and use data in Denmark. In this case, practically all data are public (although not necessarily published) with a relatively high level of detail (quantities of individual active ingredient per crop), enabling quite detailed spatialization.

3.4 France

Ms Christine Veyrac of the French Ministry of Agriculture and Food presented the situation in France. In this case, a comprehensive published database exists containing data on individual active ingredient sales at National level. A wealth of surveys on pesticide use are available, but in a less systematic way. This additional information is mainly useful in order to suggest criteria for the attribution of national data to crops and regions, as well as for the evaluation of the error associated with considering sold quantities as a proxy for used quantities.

3.5 Germany

Mr Joern Strassemeyer of the Julius-Kuehn Institut illustrated the approach to pesticide risk mapping in Germany as well as the available data. Sales data for individual active ingredients are available only with indication of the order of magnitude or ranges of quantities, but not the actual amount. Pesticide use is investigated at a number of “reference” farms throughout the country.

3.6 Ireland

Mr James Quirke of the Pesticide Controls Division, Department of Agriculture, Food and the Marine of Ireland illustrated the information available in Ireland. While pesticide sales data are covered by confidentiality and only published as broad group totals, in Ireland there is a systematic approach to pesticide use surveying. Data on pesticide use are therefore available and can be used to make spatial estimates.

3.7 Italy

Mr Francesco Galimberti of the International Centre for Pesticides and Health Risk Prevention (ICPS) illustrated the proposed approach to model pesticide use taking Italy as a starting example. Spatially disaggregated sales data on individual active ingredients are available for Italy up to 2012. The approach associates each active ingredient to different crops based on national authorization information, and regional sales are attributed to municipal level in Italy, based on the distribution of crops (Figure 2). The approach is applicable at European scale provided that a link can be established between active ingredients and their target crops. Moreover, where sales or use data on individual active ingredients are not available it will be necessary to estimate a percentage of sales of each active ingredient relative to the total amount sold in its broad group (herbicides, insecticides, fungicides etc.).

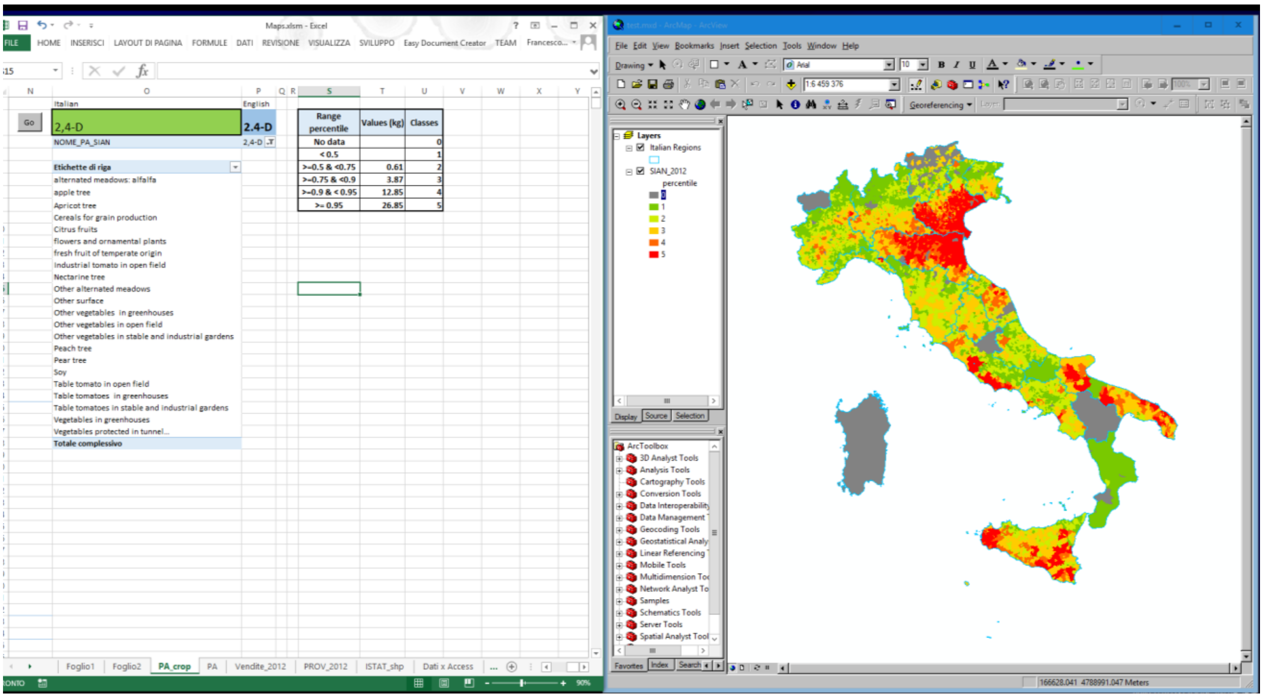


Figure 2 – example of map of use of pesticide 2,4 D estimated for Italy. [1]

3.8 Poland

Mr Mariusz Wojciechowski from the Polish Statistical Office presented the data available in Poland. For individual active ingredients, sales data are protected by confidentiality and only published in aggregated form. In terms of pesticide use, a breakdown of the total quantity by broad group among the most used active ingredients can be made available upon request.

3.9 Portugal

Ms Miriam Cavaco, Head of the Management and Authorization of Plant Protection Products Unit of the General Directorate for Food and Veterinary of the Portuguese Ministry of Agriculture, Forestry and Rural Development, illustrated the situation in Portugal. As in other member states, the competent authority discloses in his web site the aggregated sales data as already available at EUROSTAT. But in Portugal there is information available on the crops and pests in which is authorised and used each plant protection product (active ingredient). Moreover, Portuguese provisions oblige farmers to follow the recomendations of the label. The labels are autorised by the competent autority and advice farmers to follow the minimum effective dose autorised, and in the labels of the plant protection products in order to prevent pest resistance. This provides criteria to estimate the use of individual active ingredients for Portugal, which can to some (limited) extent surrogate “real” pesticide use statistics.

3.10 The Netherlands

Mr Rob Vijftigschild of the Dutch Statistics institute presented the data available for the Netherlands. Also in this case sales data are confidential and only presented in aggregated form (by main groups of substances), while use of each active ingredient is estimated from a survey of about 4,000 farms representing the majority of pesticide users. Use data are made publicly available through online databases. Sales data have also become non-confidential in 2019, and will become gradually available in the near future.

3.11 Slovakia

Ms Bronislava Skarbova of the Slovak Ministry of Agriculture and Rural Development presented pesticide data management in Slovakia, where pesticide use by professional farmers is supposed to be recorded through a

[1] The values presented in the maps result from spatial estimates which were not yet validated. Their purpose is merely illustrative and does not allow drawing conclusions on the spatial patterns in use, and related risks, of the chemicals.

centralized online system. While both use and sales data are protected by confidentiality, the Ministry is available to distribute data packages with an appropriate level of aggregation upon request for use by public authorities.

4 Available national data on the use or sales of individual active ingredients

In this section, we briefly outline the data accessible for individual countries in the EU. These data were subsequently used for the mapping of pesticide use at European scale.

4.1 Belgium

Data on the sales of individual active substances (AS) in Belgium are available at https://fytoweb.be/fr/plan-de-reduction/vigilance/donnees-de-vente.

Spatial resolution: Country level

Temporal coverage (years): from 2011 to 2017

Processing required:

- Translation and harmonisation to into a JRC active substance use database
- From the file provided, all the information about quantities of pesticides sold for application on crops were retrieved; for each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT data: https://ec.europa.eu/EUROSTAT/web/agriculture/data/database).
- Spatialization of total AS to NUTS3 based on agricultural statistics. We mapped the use (kg) for each NUTS3 level region as an average of data from 2011 to 2017, assuming sales as a proxy for use.

4.2 Denmark

Data on the sale of individual active substances (AS) in Denmark are published in a report accessible at: https://www2.mst.dk/Udgiv/publikationer/2014/12/978-87-93283-33-6.pdf

Spatial resolution: Country level

Temporal coverage (years): 2012-17

Processing required:

- Translation and harmonisation to into a JRC active substance use database
- due to the additional difficulty of extracting the data from the pdf document instead of a database, as a first attempt, we only retrieved a list of quantities of all pesticides sold in Denmark from the Bekæmpelsesmiddel-statistik 2013 report. In addition, the application of a subset of the pesticide list on crops was retrieved too, in terms of percentages of AS applied on crops; for each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT).

It should be noted that 2013 was a special year because the Danish pesticide tax was changed from a value-based tax to a quantity-based tax differentiated according to health and environmental criteria. The change in the taxation resulted in stockpiling of pesticides by the Danish farmers, as the tax was expected to rise for some pesticides. Therefore the pesticide sales data from 2013 are not representative for the use of pesticides in the Denmark. Even taking the average for the period 2012-2017, the sales data would still not be fully representative. This aspect will be further addressed in the development of the work.

- Spatialization of total AS to NUTS3 based on agricultural statistics.

4.3 France

Data on the use of individual active substances (AS) in France are accessible at: http://www.data.eaufrance.fr/jdd/bd45f801-45f7-4f8c-b128-a1af3ea2aa3e

Spatial resolution: Département level (NUTS3)

Temporal coverage (years) 2010-2017

Processing required:

- Translation and harmonisation to into a JRC active substance use database

- A list of Plant Protection Products mainly sold in France was provided with digitalized Pesticide Product Labels. A series of information were extracted from the Pesticide Labels such as the content of active ingredients in the PPP and the authorized uses on crops. Each crop was assigned to an agricultural EUROSTAT group.

- Spatialization of total AS to NUTS3 based on agricultural statistics. We mapped the use (kg) for each NUTS3 level region as an average of data from 2010 to 2017.

4.4 Germany

Data on the use of individual active substances (AS) in Germany were provided directly by the expert in the form of MS Excel © spreadsheets.

Spatial resolution: national level

Temporal coverage (years): 2017

Thematic coverage: 9 crops (barley, wheat, corn, rape, hop, potatoes, sugar beet, apples, grapes)

Used metrics: treated surface ("behandelte Fläche (Mittelwert, in ha)"), total AS used ("WS-Menge (Schätzung, in kg)")

Processing required:

- Translation and harmonisation to into a JRC active substance use database.

- For each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT).

- Spatialization of total AS to NUTS3 based on agricultural statistics.

4.5 Ireland

Data on the use of individual active substances (AS) in Ireland are accessible at http://www.pcs.agriculture.gov.ie/sud/pesticidestatistics/

Spatial resolution Country level

Temporal coverage (years) from 2011 to 2015 (surveys on different crops per year)

Processing required:

- Translation and harmonisation to into a JRC active substance use database.

- For each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT).

- Spatialization of total AS to NUTS3 based on agricultural statistics

4.6 Italy

Data on the sales of individual active substances (AS) in Italy are accessible at: https://www.sian.it

Spatial resolution Regional level

Temporal coverage (years) 2012

Processing required:

- Translation and harmonisation to into a JRC active substance use database.

- A list of all Plant Protection Products sold in Italy was retrieved from the online database Pestidoc (www.icps.it/PESTIDOC) with digitalized Pesticide Product Labels. A series of information were extracted from the Pesticide Labels such as the active ingredient content in the PPP and the authorized uses on crops. For each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT).

- A list of quantities of pesticide chemical families at Provincial level was retrieved from the SIAN website: this information was used to increase the level of detail of the spatialized data from Regional scale to Provincial Level.

- Spatialization of total AS to NUTS3 based on agricultural statistics

4.7 The Netherlands

Data on the sales of individual active substances (AS) in the Netherlands are accessible at https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84010NED/table?dl=1CE23

Spatial resolution Country level

Temporal coverage (years) 2012 and 2016

Processing required:

- Translation and harmonisation to into a JRC active substance use database.

- From the website, all the information about kg, ha and kg/ha of pesticides on crops were retrieved. For each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT).

- Spatialization of total AS to NUTS3 based on agricultural statistics. The resulting kg per NUTS3 is an average of kg of active substance in 2012 and 2016.

4.8 Spain

Data on the use of individual active substances (AS) in Spain are accessible at https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/estadisticas-medios-produccion/fitosanitarios.aspx (Bottom page: 'Encuesta de Utilización de Productos Fitosanitarios': Tablas datos de utilización 2013 (EUPF13))

Spatial resolution: national level

Temporal coverage (years): 2013

Thematic coverage: 7 crops (barley, citrus, sunflower, vegetables, olives, wheat, grapes)

Used metrics: treated surface ("Superficie tratada cultivada (ha)"), total AS used ("Total Sustancia (kg)")

Processing required:

- Translation and harmonisation to into a JRC active substance use database.

- From the website, all the information about kg, ha and kg/ha of pesticides on crops were retrieved. For each crop reported, a correspondence was established with the available agricultural statistics (EUROSTAT).

- Spatialization of total AS to NUTS3 based on agricultural statistics.

4.9 Data for model verification: Slovakia and UK

Although data on AS for Slovakia could not be used due to confidentiality constraints, these were provided by the expert for internal use only. Data on the quantity of each active ingredient used in Slovakia will be only used for a verification of the estimates the JRC is preparing for the whole EU (see § 5), fully respecting confidentiality.

Data on the use of individual AS for the UK are publicly accessible at: https://secure.fera.defra.gov.uk/pusstats/ . The data were retrieved and organized in a JRC database for use in the verification of estimates, along with data from Slovakia.

5 Spatialization of pesticide use

The pesticide (sales or use) data presented above come from different sources, and the purpose and method for data collection differed from country to country. As a first step, pesticide use or sales data were associated with crops. In order to harmonize the results, we referred to EUROSTAT agricultural statistics (2016). These were downloaded from the EUROSTAT website with a NUTS2 spatial resolution. To increase the spatialization detail of pesticide use at European scale, we made use of Corine Land Cover (CLC). A correspondence was established between CLC classes and EUROSTAT Agricultural statistics crop categories (Table 1).

Land cover	**CLC Legend Classes**	**EUROSTAT crop statistics codes**
ARABLE	211+212	ARA-C2000
RICE	213	C2000
FRUIT TREES	222	F0000 + T0000
GRASS	231+241+242+243+244	J0000
OLIVES	223	O1000
VINEYARDS	221	W1000

Table 1 – correspondence of CLC classes and EUROSTAT crops as used in this work.

We checked that the extent of each CLC land cover class (or group of classes) and the corresponding crops were compatible at NUTS2 level. Results of this comparison are presented in the following figures, highlighting that the correspondence is quite good for all the classes, with the partial exception of grass/pastures group. In general, EUROSTAT areas are smaller than CLC areas as expected, with the exception of rice fields possibly due to classification errors in CLC.

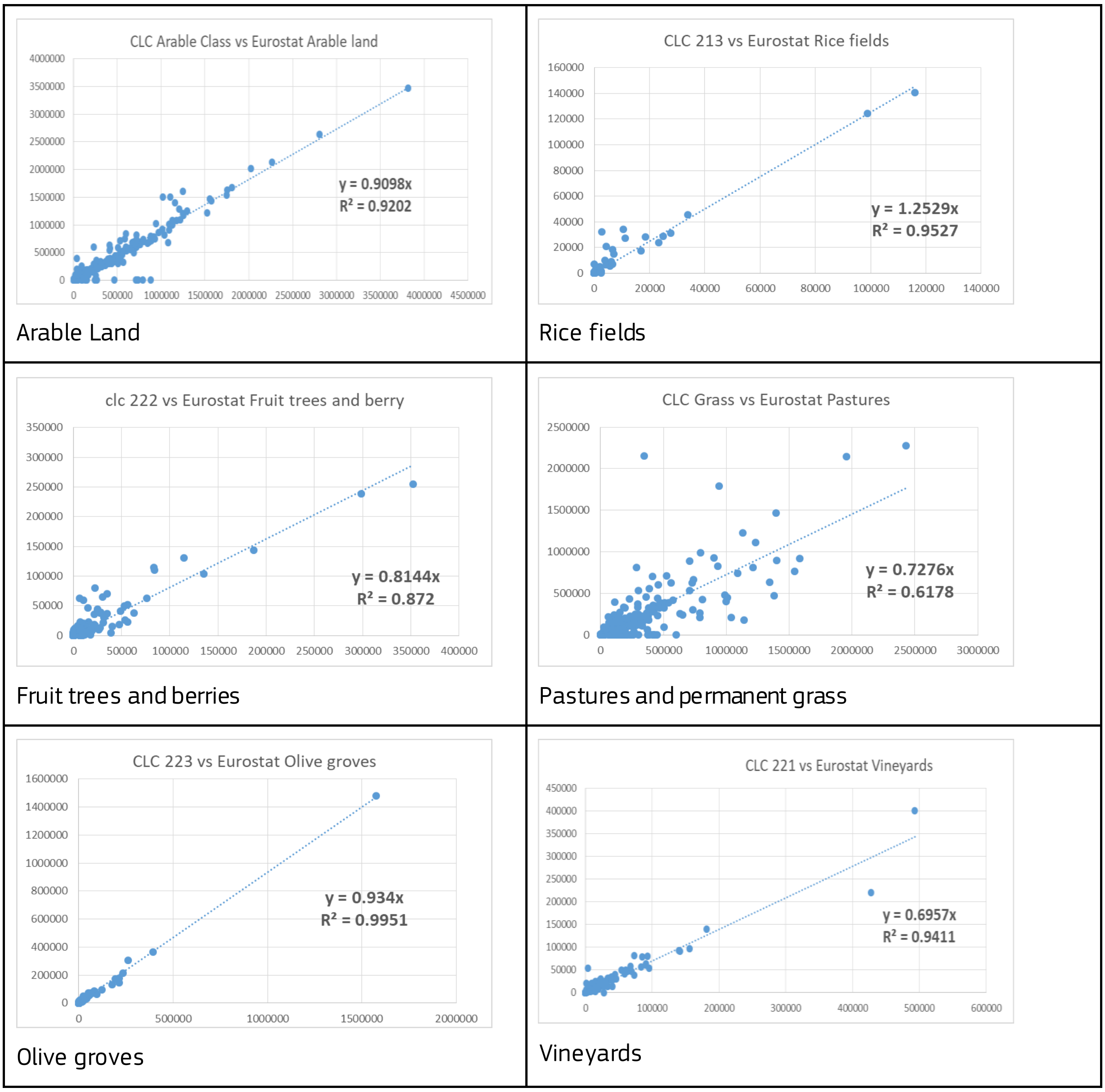


Figure 3 - Corine Land Cover class (or group of classes) area at NUTS2 level, on the x-axis, versus EUROSTAT Agricultural Statistics (crop areas at NUTS2 region level), on the y axis.

Based on the acceptable match between CLC classes and EUROSTAT crops, NUTS2 agricultural crop statistics were apportioned to NUTS3 regions based on CLC class areas. The ratio of NUTS3/NUTS2 area calculated for each CLC class was interpreted as the share of the NUTS2 EUROSTAT Agricultural Statistics crop extent in each NUTS3 region. The resulting value is the extent in hectares of each EUROSTAT agricultural crop category at NUTS3. For example, the EUROSTAT Agricultural class C1120 - Durum wheat belongs to Corine Land Cover ARABLE parent group, so that:

$NUTS3_{CLCArable}/NUTS2_{CLCArable} \times C1120_{NUTS2}\ (ha) = C1120_{NUTS3}\ (ha)$

This procedure was validated with available NUTS3 example data, and with NUTS3 data on average, of the first decade of 2000 with good results also considering the land cover evolution in the last 10 years.

Figure 4 (continues)

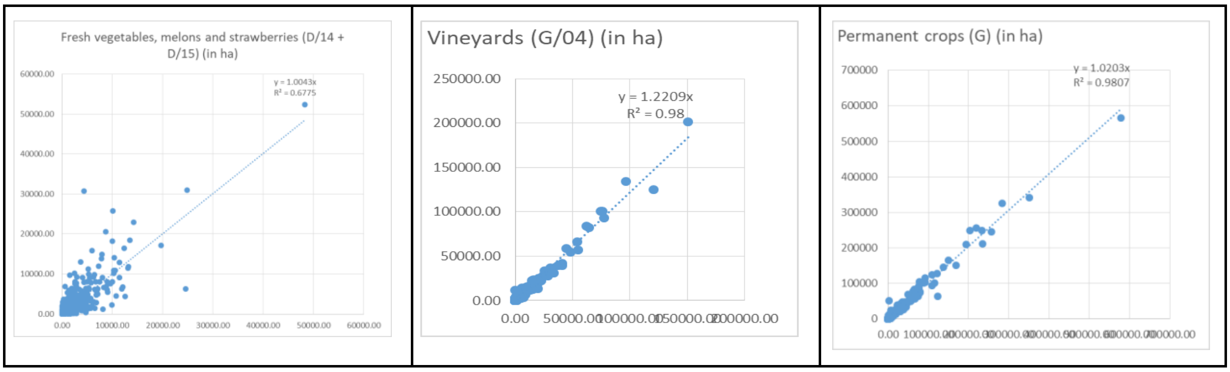


Figure 4 – comparison of the extent of EUROSTAT agricultural classes estimated at NUTS3 level (2016 data) vs extent of EUROSTAT agricultural classes natively reported at NUTS3 level for the year 2000.

The NUTS3 EUROSTAT crop class extents (ha), calculated as shown above, were the new agricultural layer for the spatialization of pesticide quantities (hereinafter “crop layer”).

Data for Italy and France were already distributed by NUTS3 level. The use of pesticides was therefore spatialized through information on the crops where each AS is authorized, and the crop layer.

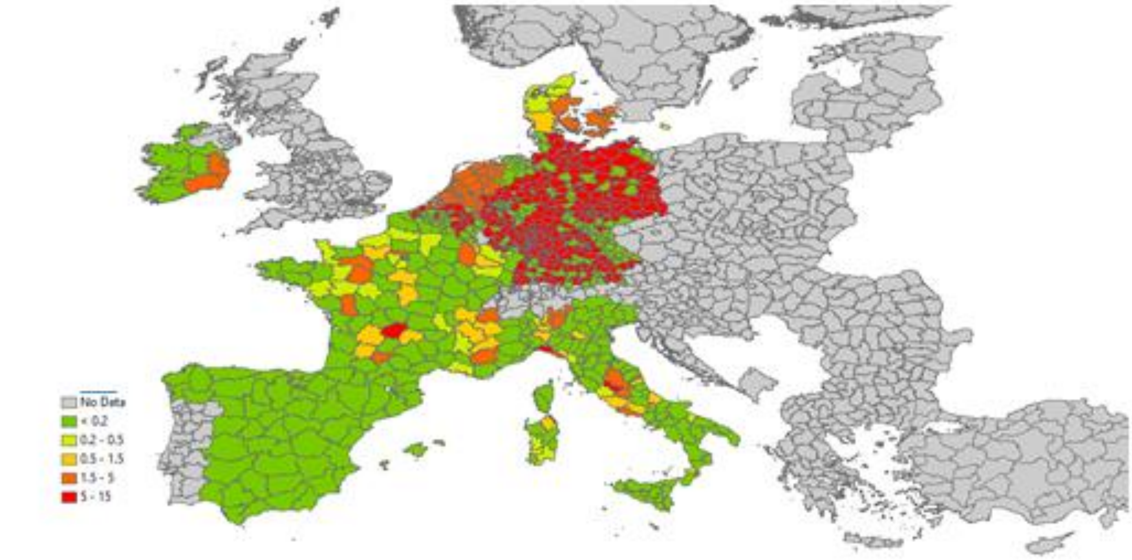
Data for Germany and Spain were already distributed by NUTS3 level and by crops. Therefore we simply attributed the data to NUTS3 regions through a correspondence established between the crops reported by these countries and EUROSTAT crop categories, without further processing.

Data for Belgium and the Netherlands were available as totals at National level for each crop where an AS was authorized. Use of pesticides at level NUTS3 was calculated according to the ratio NUTS3/NUTS2 for each AS and crop.

Data for Denmark and Ireland were aggregated at National level and divided by authorized crops in terms of percentages of application of pesticides on crops. Use of pesticides was calculated according to the ratio NUTS3/NUTS2 for each authorized crops and to the distribution of authorized uses of the Active substance on crops.

The results of these calculations are maps of each AS in the 8 countries for which data could be retrieved. Example maps for two AS are shown in Figure 5.

Table 2 summarizes the AS considered in this work, the countries where emission (use or sales) data are available, and the countries where it is authorized. All in all, we could retrieve data on use or sales of 310 AS, 283 of which are authorized in at least one country. About 1/3 of these is authorized in 25 or more countries in the EU (Figure 6), while 27 of the AS for which emissions data are provided in some of the 8 countries may not be authorized in those countries. For the 27 substances for which we have emissions but not an authorization, one possible reason could be that authorization was withdrawn after the years for which emission data are available.



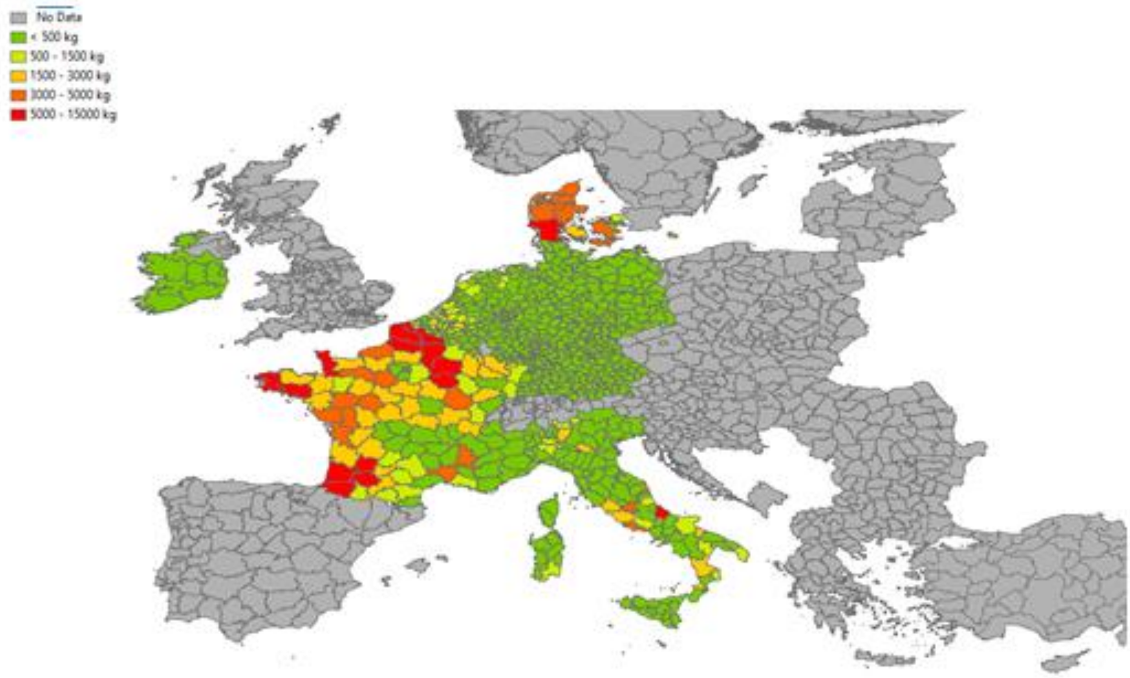


Figure 5 - Example harmonized maps of Captan (above, ***kg ha^{-1}*** *by NUTS3) and Bentazone (below,* ***kg*** *by NUTS3) use[2]*

[2] The values presented in the maps result from spatial estimates which were not yet validated. Their purpose is merely illustrative and does not allow drawing conclusions on the spatial patterns in use, and related risks, of the chemicals.

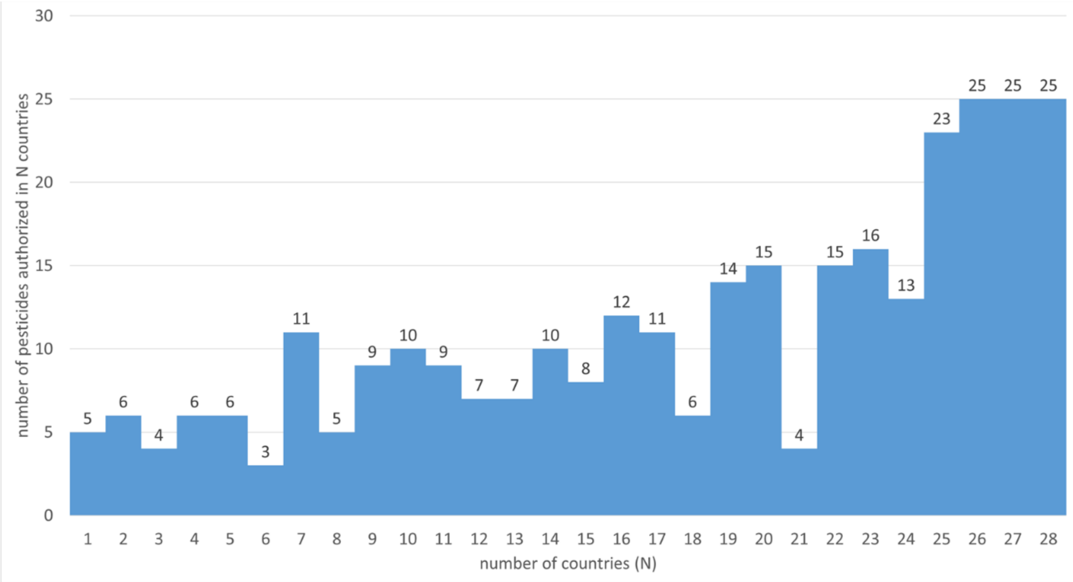


Figure 6 - statistics on the number of countries in which the AS considered here are authorized.

Active Substance	BE	DE	DK	ES	FR	IE	IT	NL	AT	BG	CY	CZ	EE	EL	FI	HR	HU	LT	LU	LV	MT	PL	PT	RO	SE	SI	SK	UK	Tot.Auth
1-Naphthylacetic acid (1-NAA)																													15
1-Decanol																													10
1-Methyl-cyclopropene																													23
1-Naphthylacetamide (1-NAD)																													9
2,4-D																													28
2,4-DB																													10
Geraniol																													7
6-Benzyladenine																													22
8-Hydroxyquinoline incl. oxyquinoleine																													11
Abamectin (aka avermectin)																													28
Acequinocyl																													13
Acetamiprid																													26
Acetic acid																													11
Acibenzolar-S-methyl																													7
Aclonifen																													23
Acrinathrin																													7
Alpha-Cypermethrin																													25
Aluminium phosphide																													28
Aluminium sulphate																													1
Amidosulfuron																													25
Aminopyralid																													23
Amisulbrom																													22
Azadirachtin (Margosa extract)																													22
Azimsulfuron																													8
Azoxystrobin																													28
Beflubutamid																													9
Benalaxyl																													17
Benalaxyl-M																													16
Benfluralin																													9
Bensulfuron methyl																													7
Bentazone																													25
Benthiavalicarb																													19
Benzoic acid																													13
Beta-Cyfluthrin																													23
Bifenazate																													22
Bifenox																													19
Bifenthrin																													1
Bispyribac																													6
Boscalid (formerly nicobifen)																													28
Bromadiolone																													3
Bromoxynil																													23
Bromuconazole																													12
Bupirimate																													16
Buprofezin																													11
Captan																													24
Carbetamide																													7
Carboxin																													14
Carfentrazone-ethyl																													19
Chlorantraniliprole																													22
Chloridazon (aka pyrazone)																													12
Chlormequat																													26
Chlorothalonil																													25
Chlorotoluron																													20
Chlorpropham																													26

Legend
Auth.& Emissions
Auth.
No Auth.& Emissions
No Auth.

Table 2 (continues)

Active Substance	BE	DE	DK	ES	FR	IE	IT	NL	AT	BG	CY	CZ	EE	EL	FI	HR	HU	LT	LU	LV	MT	PL	PT	RO	SE	SI	SK	UK	Tot.Auth
Chlorpyrifos																													20
Chlorpyrifos-methyl																													17
Chlorsulfuron																													8
Clethodim																													25
Clodinafop																													14
Clofentezine																													17
Clomazone																													27
Clopyralid																													27
Clothianidin																													12
Copper compounds																													13
Copper hydroxide																													20
Copper oxychloride																													19
Copper oxide																													9
Cyazofamid																													27
Cycloxydim																													27
Cyflufenamid																													25
Cyhalofop-butyl																													5
Cymoxanil																													27
Cypermethrin																													28
Cyproconazole																													25
Cyprodinil																													28
Cyromazine																													10
Daminozide																													19
Dazomet																													19
Deltamethrin																													28
Desmedipham																													26
Dicamba																													27
Dichlorprop-P																													22
Diclofop																													4
Diethofencarb																													2
Difenoconazole																													28
Diflubenzuron																													14
Diflufenican																													28
Dimethachlor																													16
Dimethenamid-P																													23
Dimethoate																													23
Dimethomorph																													27
Dimoxystrobin																													16
Diquat (dibromide)																													27
Dithianon																													28
Diuron																													2
Dodemorph																													5
Dodine																													27
Emamectin																													15
Epoxiconazole																													24
Esfenvalerate																													22
Ethephon																													25
Ethofumesate																													26
Ethoprophos																													10
Ethylene																													15
Etofenprox																													14
Etoxazole																													16
Etridiazole																													3
Famoxadone																													20

Legend

- Auth.& Emissions
- Auth.
- No Auth.& Emissions
- No Auth.

Table 2 (continues)

Active Substance	BE	DE	DK	ES	FR	IE	IT	NL	AT	BG	CY	CZ	EE	EL	FI	HR	HU	LT	LU	LV	MT	PL	PT	RO	SE	SI	SK	UK	Tot.Auth
Fenamidone																													19
Fenamiphos (aka phenamiphos)																													7
Fenazaquin																													7
Fenbuconazole																													9
Fenhexamid																													24
Fenoxaprop-P																													25
Fenoxycarb																													14
Fenpropidin																													25
Fenpropimorph																													23
Fenpyroximate																													18
Flonicamid (IKI-220)																													25
Florasulam																													28
Fluazifop-P																													26
Fluazinam																													27
Flubendiamide																													2
Fludioxonil																													28
Flufenacet (formerly fluthiamide)																													23
Flumioxazine																													16
Fluopicolide																													27
Fluopyram																													27
Fluoxastrobin																													17
Fluquinconazole																													4
Flurochloridone																													11
Fluroxypyr																													26
Flurtamone																													9
Flutolanil																													20
Flutriafol																													13
Folpet																													27
Foramsulfuron																													26
Forchlorfenuron																													6
Formetanate																													10
Fosetyl																													28
Fosthiazate																													16
Gamma-cyhalothrin																													11
Glufosinate																													11
Glyphosate (incl trimesium aka sulfosate)																													28
Halosulfuron methyl																													5
Haloxyfop-P (Haloxyfop-R)																													10
Heptamaloxyloglucan																													1
Hexythiazox																													22
Hymexazol																													17
Imazalil (aka enilconazole)																													25
Imazamox																													26
Imazaquin																													5
Imidacloprid																													22
Indolylbutyric acid																													12
Indoxacarb																													28
Iodosulfuron																													27
Ipconazole																													19
Iprovalicarb																													16
Isoxaben																													13
Isoxaflutole																													20
Kresoxim-methyl																													27
lambda-Cyhalothrin																													27

Legend

- Auth.& Emissions
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Table 2 (continues)

Active Substance	BE	DE	DK	ES	FR	IE	IT	NL	AT	BG	CY	CZ	EE	EL	FI	HR	HU	LT	LU	LV	MT	PL	PT	RO	SE	SI	SK	UK	Tot.Auth
Laminarin																													10
Lenacil																													19
Lime sulphur (calcium polysulphid)																													4
Lufenuron																													9
Magnesium phosphide																													23
Malathion																													8
Maleic hydrazide																													21
Maltodextrin																													7
Mancozeb																													28
Mandipropamid																													28
MCPA																													28
MCPB																													15
Mecoprop-P																													24
Mepanipyrim																													16
Mepiquat																													24
Meptyldinocap																													14
Mesosulfuron																													26
Mesotrione																													26
Metaflumizone																													10
Metalaxyl																													12
Metalaxyl-M																													28
Metaldehyde																													25
Metam (incl. -potassium and -sodium)																													13
Metamitron																													26
Metazachlor																													26
Metconazole																													25
Methiocarb (aka mercaptodimethur)																													22
Methomyl																													9
Methoxyfenozide																													20
Metiram																													19
Metobromuron																													26
Metosulam																													2
Metrafenone																													26
Metribuzin																													27
Metsulfuron-methyl																													27
Milbemectin																													20
Myclobutanil																													19
Napropamide																													24
Nicosulfuron																													25
Oryzalin																													4
Oxadiazon																													3
Oxamyl																													17
Oxasulfuron																													1
Oxyfluorfen																													11
Paclobutrazol																													22
Paraffin oil/(CAS 64742-46-7)																													8
Paraffin oil/(CAS 72623-86-0)																													4
Paraffin oil/(CAS 8042-47-5)																													20
Penconazole																													26
Pencycuron																													17
Pendimethalin																													27
Penoxsulam																													14
Pethoxamid																													18
Phenmedipham																													27

Legend

- Auth.& Emissions
- Auth.
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Table 2 (continues)

Active Substance	BE	DE	DK	ES	FR	IE	IT	NL	AT	BG	CY	CZ	EE	EL	FI	HR	HU	LT	LU	LV	MT	PL	PT	RO	SE	SI	SK	UK	Tot.Auth
Phosmet																													14
Picloram																													18
Picolinafen																													14
Pinoxaden																													25
Pirimicarb																													21
Pirimiphos-methyl																													20
Eugenol																													7
Potassium phosphonates (formerly potassium p																													24
Prochloraz																													24
Profoxydim																													5
Prohexadione																													26
Propamocarb																													28
Propaquizafop																													26
Propiconazole																													26
Propineb																													8
Propoxycarbazone																													19
Propyzamide																													23
Proquinazid																													25
Prosulfocarb																													27
Prosulfuron																													20
Prothioconazole																													26
Pymetrozine																													26
Pyraclostrobin																													28
Pyraflufen-ethyl																													17
Pyridaben																													12
Pyridalyl																													1
Pyridate																													28
Pyrimethanil																													26
Pyriproxyfen																													17
Pyroxsulam																													27
Quinmerac																													23
Quinoclamine																													11
Quinoxyfen																													19
Quizalofop-P																													7
Quizalofop-P-ethyl																													23
Rimsulfuron (aka renriduron)																													27
Silthiofam																													17
Sintofen (aka Cintofen)																													5
S-Metolachlor																													20
Spinetoram																													10
Spinosad																													24
Spirodiclofen																													22
Spiromesifen																													11
Spirotetramat																													25
Spiroxamine																													24
Sulcotrione																													15
Sulfosulfuron																													15
Sulfuryl fluoride																													10
tau-Fluvalinate																													25
Tebuconazole																													28
Tebufenozide																													12
Tebufenpyrad																													17
Teflubenzuron																													3
Tefluthrin																													20

Legend

- Auth.& Emissions
- Auth.
- No Auth.& Emissions
- No Auth.

Table 2 (continues)

Active Substance	BE	DE	DK	ES	FR	IE	IT	NL	AT	BG	CY	CZ	EE	EL	FI	HR	HU	LT	LU	LV	MT	PL	PT	RO	SE	SI	SK	UK	Tot.Auth
Tembotrione																													19
Terbuthylazine																													22
Tetraconazole																													18
Thiabendazole																													15
Thiacloprid																													27
Thiamethoxam																													21
Thiencarbazone																													24
Thifensulfuron-methyl																													26
Thiophanate-methyl																													26
Thiram																													13
Tolclofos-methyl																													14
Tralkoxydim																													2
Triadimenol																													18
Tri-allate																													6
Tribasic copper sulfate																													15
Tribenuron (aka metometuron)																													28
Triclopyr																													16
Trifloxystrobin																													26
Triflumizole																													2
Triflumuron																													4
Triflusulfuron																													20
Trinexapac (aka cimetacarb ethyl)																													27
Triticonazole																													23
Tritosulfuron																													25
Valifenalate (formerly Valiphenal)																													18
zeta-Cypermethrin																													20
Ziram																													16
Zoxamide																													23
Ametoctradin																													24
Bixafen																													24
Isopyrazam																													21
Fenpyrazamine																													25
Cyflumetofen																													9
Penthiopyrad																													16
Fluxapyroxad																													25
Pyriofenone																													22
Sedaxane																													23
Thymol																													7
Halauxifen-methyl																													22
Benzovindiflupyr																													25

Legend
- Auth.& Emissions
- Auth.
- No Auth.& Emissions
- No Auth.

Table 2 – summary of active substances (AS) considered in this study

6 Discussion and way forward

In the different EU countries considered, pesticide sales and use data show very different levels of accessibility, from almost null to very open. Generally, sales data are more strictly covered by confidentiality than use data. The latter are based on surveys, covering various shares of the total pesticide use. However, use data seem to be more frequently represent indirect or estimated information (e.g. because they derive from extrapolations of surveys) compared to sales data.

Some countries do not make pesticide data available at the level of individual active ingredients, while others disclose these data whenever possible. As a result, in the short term the only practical possibility for the assessment of pesticide use in Europe will be to develop an estimation model to extrapolate the data of the 8 available countries to the whole of the EU. Developing a European pesticide use model, i.e. a continental scale spatial estimation of the application rates of each of the 310 active ingredients authorized/used in the EU, as resulting from the 8 countries considered here, will anyway entail a number of assumptions and will need to come to terms with the heterogeneity of information among different Member States. One possibility is to apply machine learning methods to predict pesticide use on the basis of crops, climate and other context descriptors. Preliminary results using a machine learning approach indicate that data can be actually generalized for many of the AS considered here, using the “crop layer” developed as discussed above, as well as climate data. Figure 7 shows examples of generalization of pesticide use data to all EU NUTS3 regions. A full description of the applied methods and results obtained in this way is beyond the scope of this report and will be provided in a forthcoming contribution.

Once maps of pesticide use are available for all AS, on the example shown in Figure 7, they can be used for the prediction of chemical concentrations of individual AS, as well as the estimation of their cumulative toxicity. A model of pesticide cumulative toxicity in a medium of interest (e.g., water) can be built following the structure shown in Figure 8. In essence, the model computes a cumulative toxicity indicator I for a set of n pesticides as:

$$I = \sum_{i=1}^{n} \frac{C_i}{T_i}$$

Where C_i is the concentration of the i-th AS and T_i is a concentration representing its threshold of risk (“toxicity”). Both are referred to the medium of interest (water, soil etc.). The concentration of AS is proportional to its emissions in the environment and depends on the processes causing its dilution, retention and degradation in the different media. The latter depend on the AS’s physico-chemical properties as well as on the landscape and climate parameters relevant for the different processes. The model of pesticide use outlined above serves the purpose of delivering emission estimates for each AS in the environment, i.e. the orange box at the bottom of the model structure diagram in Figure 8.

In order to obtain an emission map for each AS, the total use quantity of an AS within each NUTS3 region can be apportioned to suitable land cover classes in order to obtain a fine-scale spatialization of emissions. This requires a series of assumptions that will be discussed in a forthcoming contribution.

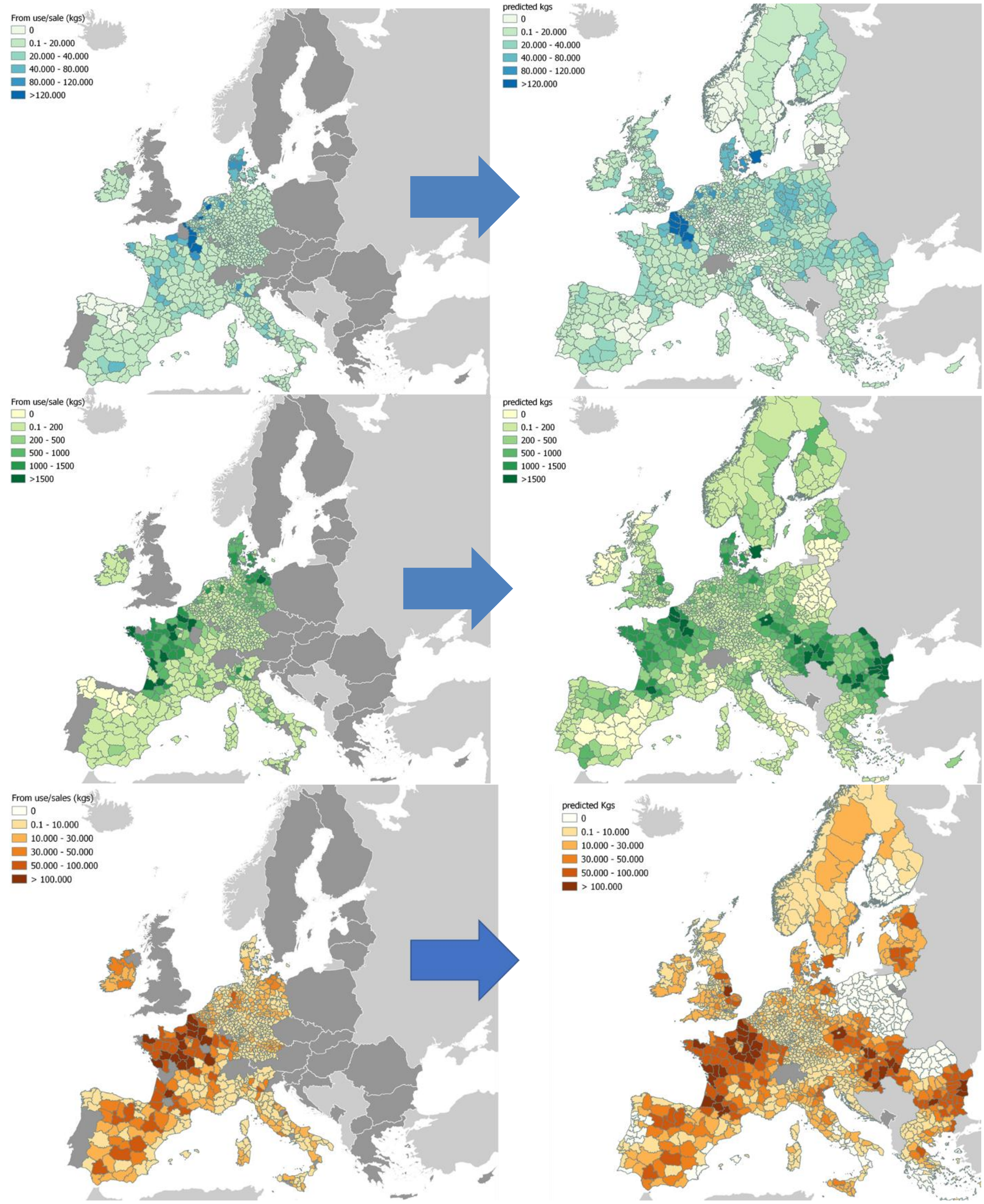

Figure 7 – example of generalization of pesticide use data (kg year^{-1} within each NUTS3 region) to the whole EU, in the case of three AS (top: Mancozeb; middle: Thiacloprid; bottom: Glyphosate). Left: maps based on harmonized data from the 8 available countries; right: pan-EU model prediction. ***The maps are purely illustrative and not validated.*** *The values presented in the maps result from very preliminary model estimates which were not yet validated, and do not allow drawing conclusions on the spatial patterns in use, and related risks, of the chemicals. As an example, Glyphosate use in Poland is predicted to be limited only to a few areas in the south of the country, while its use is known to be widespread.*

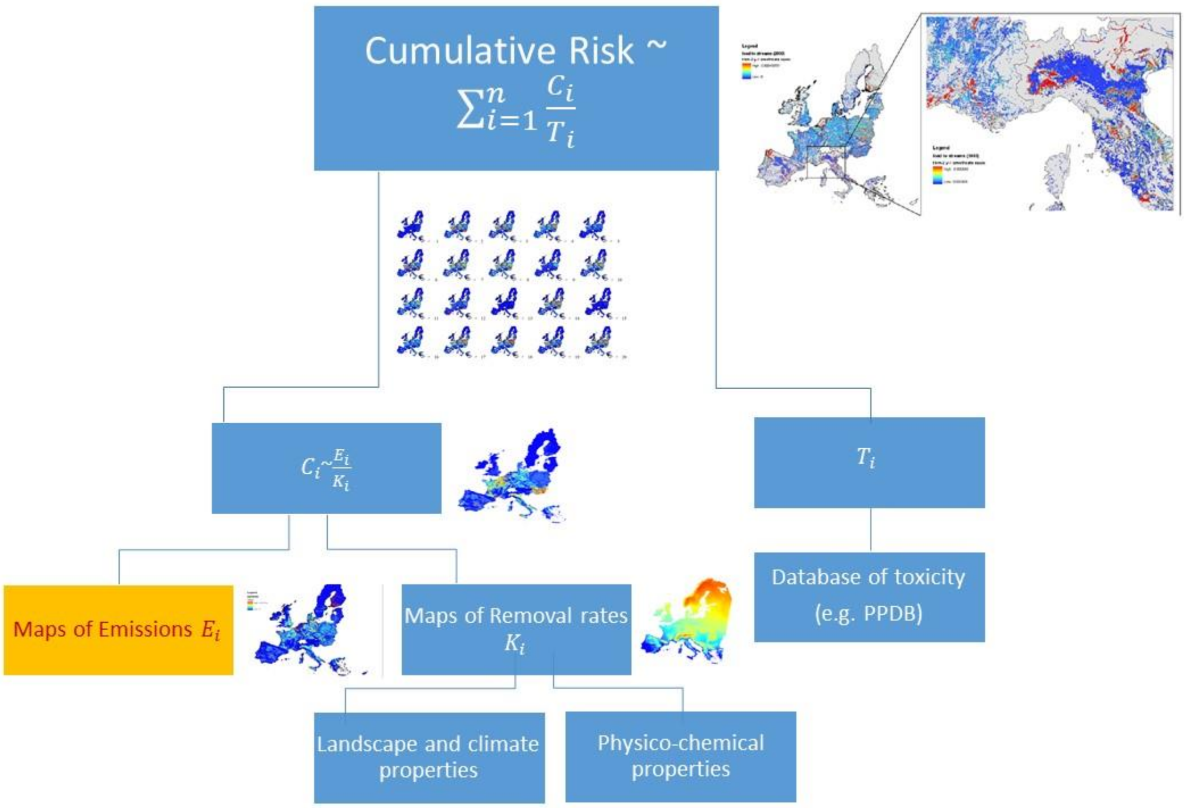

Figure 8 - Structure of a pesticide model

It should be stressed that pesticide use data should be an input to a model as outlined in Figure 8. The estimation of pesticide use outlined here is justified by lack of accessible data. In order to use this estimation for decision support, it is important to compare the model output with reported use data. In the development of the work, the model will be subjected to cross-validation as well as to validation with independent data (from Slovakia and the UK) not used for model calibration. Calibration data, in turn, suffer from heterogeneity in space (some countries provide national, some regiona data, and the breakdown by crops is not uniform) and time (the years of reporting are not the same for all countries). The "reference baseline" that we build through harmonization corresponds more to a window in time, than a specific year. Moreover, not all chemicals are necessarily covered, as some AS could be authorized in countries not included among those providing data for training. finally, certain chemicals are used upon need or region-specifically, hence their use cannot be generalized. The results of the model are anticipated to be weak in those cases.

Once AS use is estimated, a model can be applied to predict environmental concentrations. The model can be validated against observed concentrations. With concentrations computed for all AS, the cumulative toxicity indicator can be easily obtained.

In the EU there are presently 466 AS authorized, some of which pose a low risk. Our estimates will concern 283 of the 466 AS (about 60%) which should actually account for the largest part of toxicity (Figure 9). However, only for 37 (about 13%) of the AS with an estimate there will be a possibility to validate predicted concentrations against observations using the European repository IPCheM3. Moreover, within IPCheM the spatial coverage of data is limited (Figure 10), suggesting that validation may not always be representative. Maps from Figure 11 to Figure 20 show the spatial distribution of the available samples for all AS covered in IPCheM.

In spite of these limitations, the data collected through this work are expected to enable a first step towards improved modelling of chemical risk in European soils and waters.

[3] https://ipchem.jrc.ec.europa.eu/RDSIdiscovery/ipchem/index.html

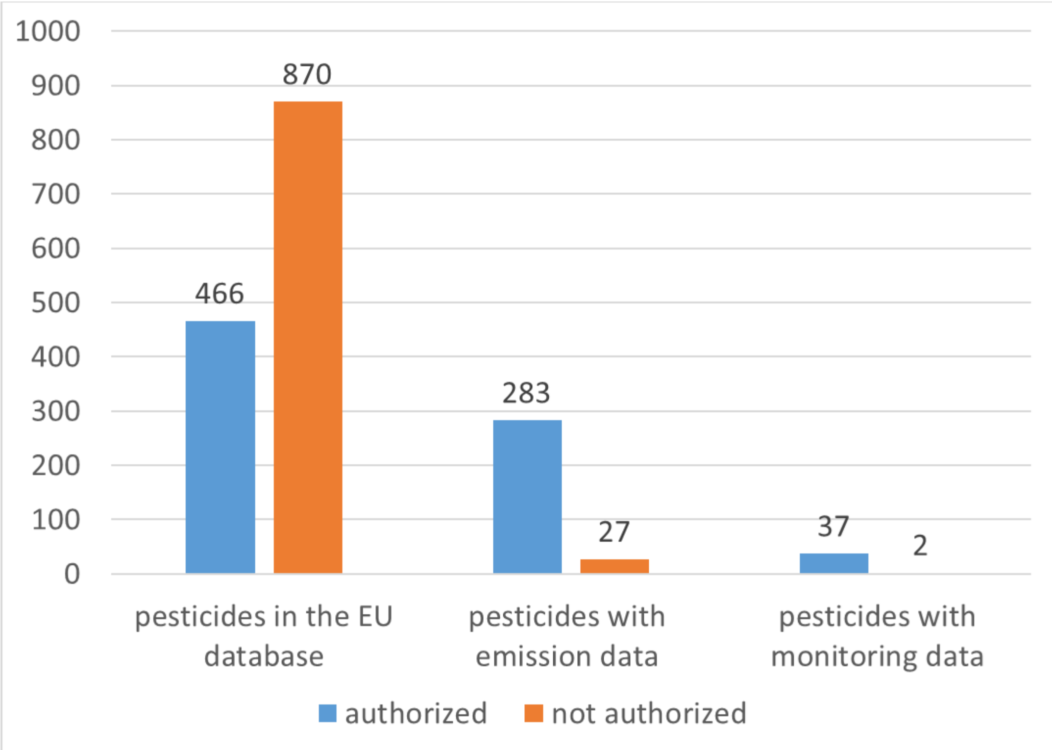

Figure 9 – AS present in the EU pesticides database[4], AS with emission data in 8 countries and with monitoring data in IPCheM

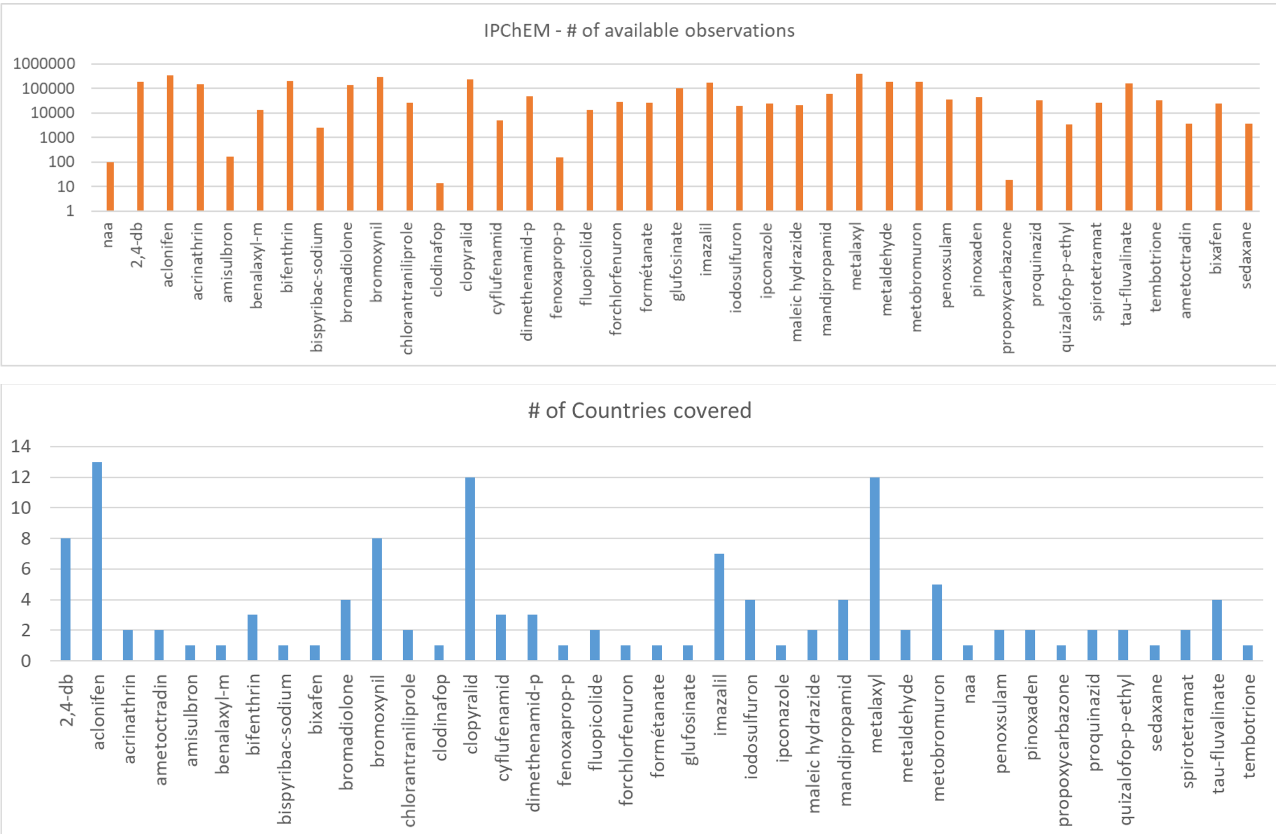

Figure 10 –observations available from IPCheM

[4] https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN

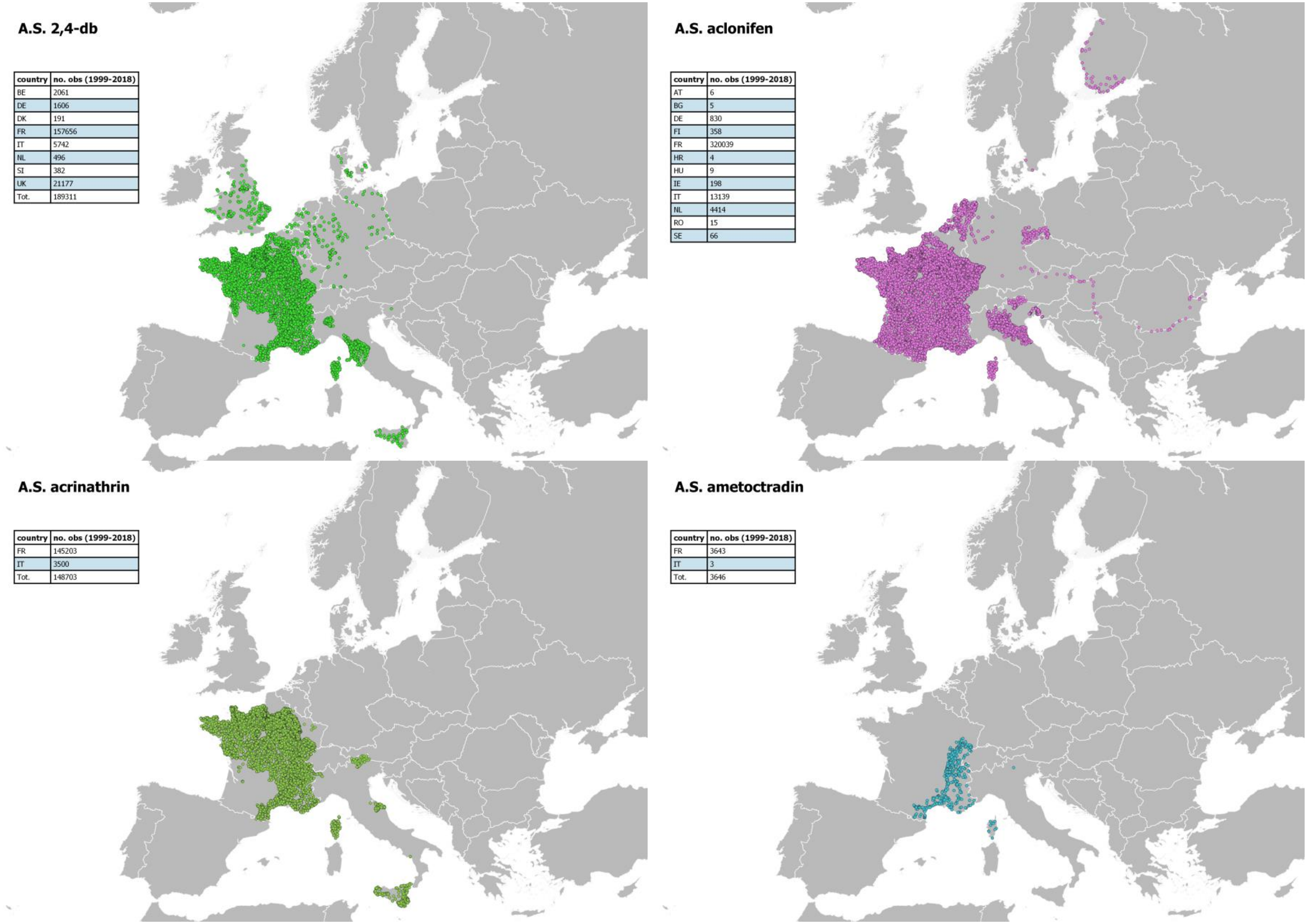

Figure 11 – samples available in IPCheM for 2,4-db, aclonifen, acrinathrin and amectoctradin

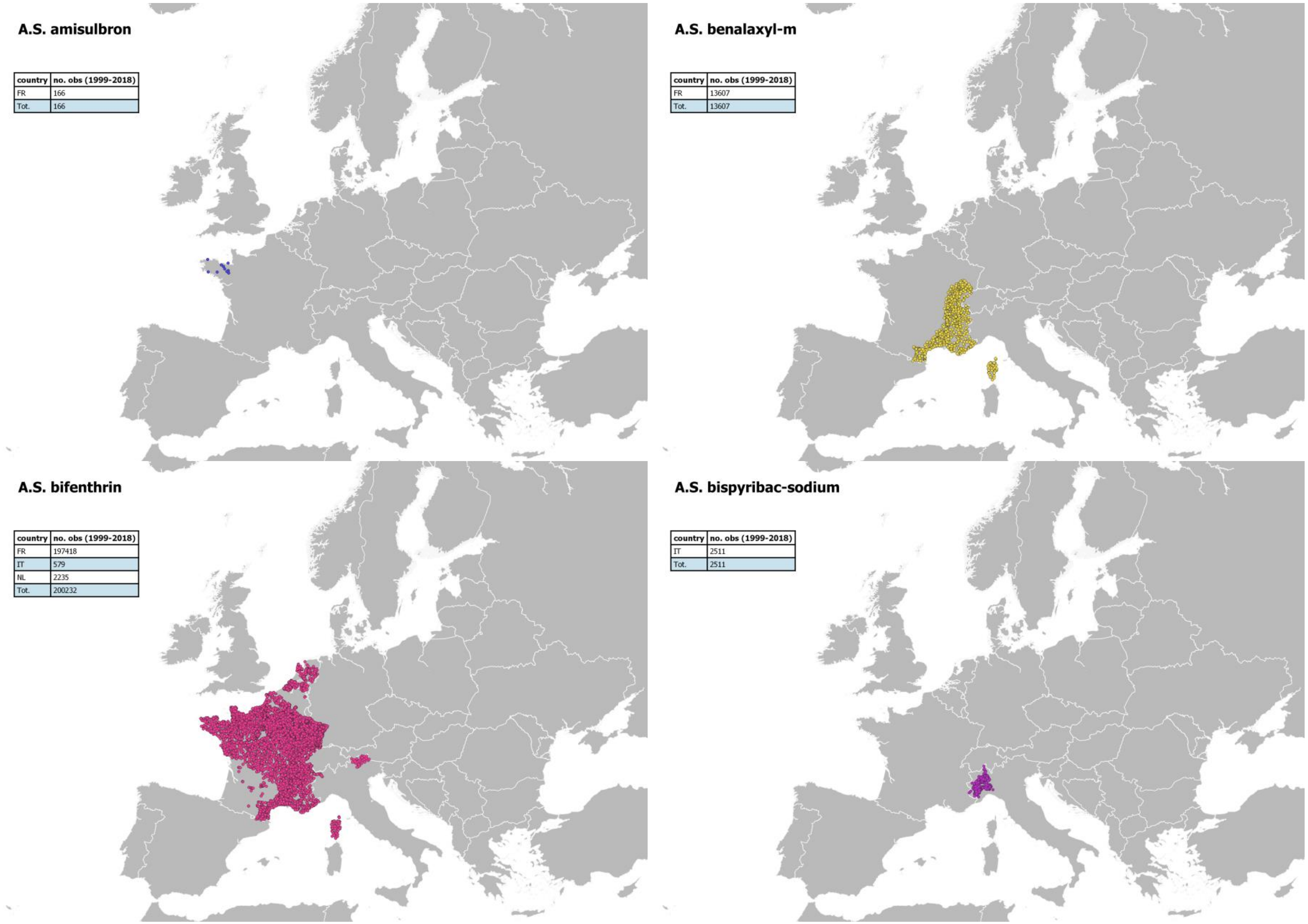

Figure 12 - samples available in IPCheM for amisulbron, benalaxyl-m, bifenthrin and bispyribac-sodium

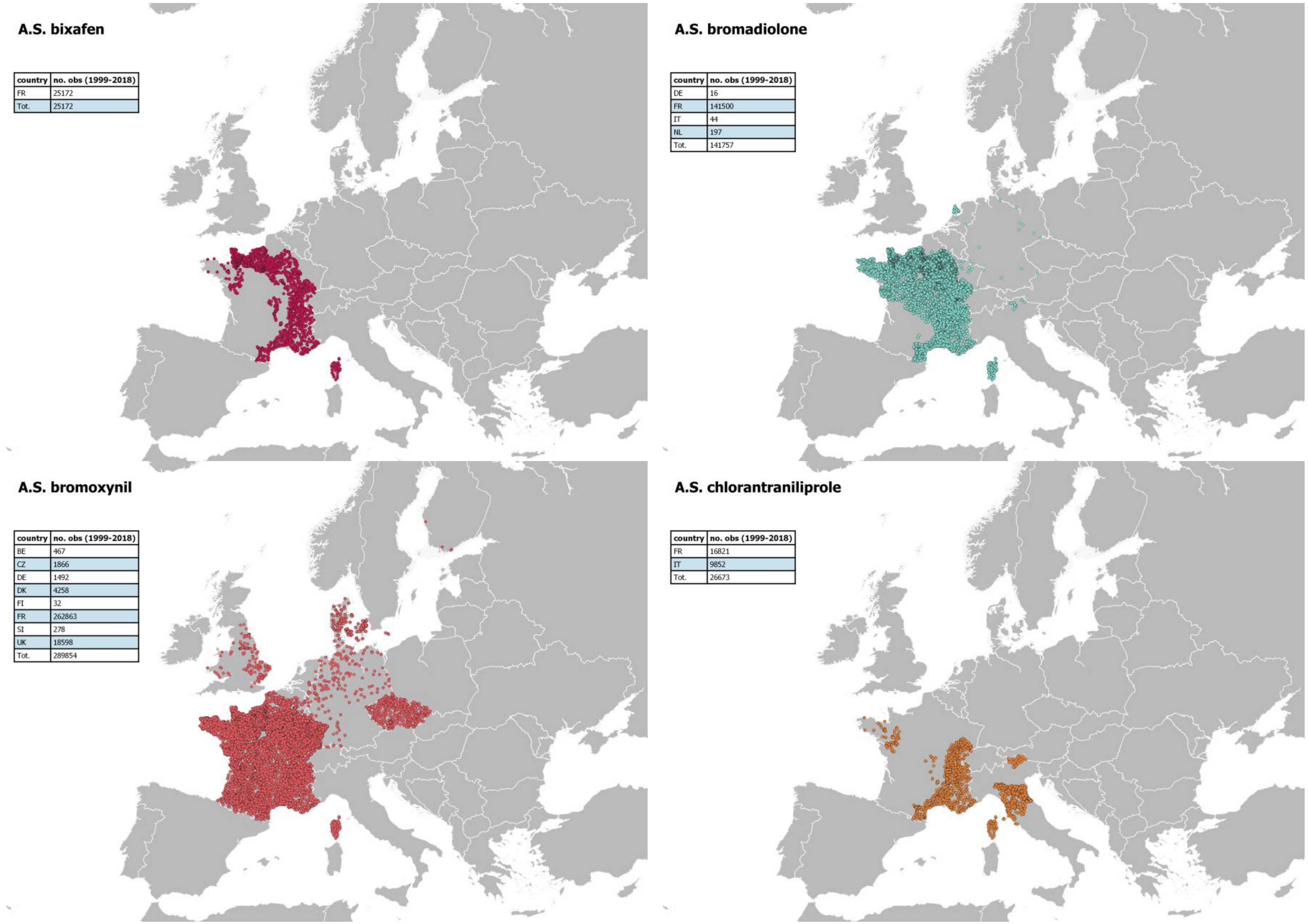

Figure 13- samples available in IPCheM for bixafen, bromadiolone, bromoxynil, chlorantraniliprole

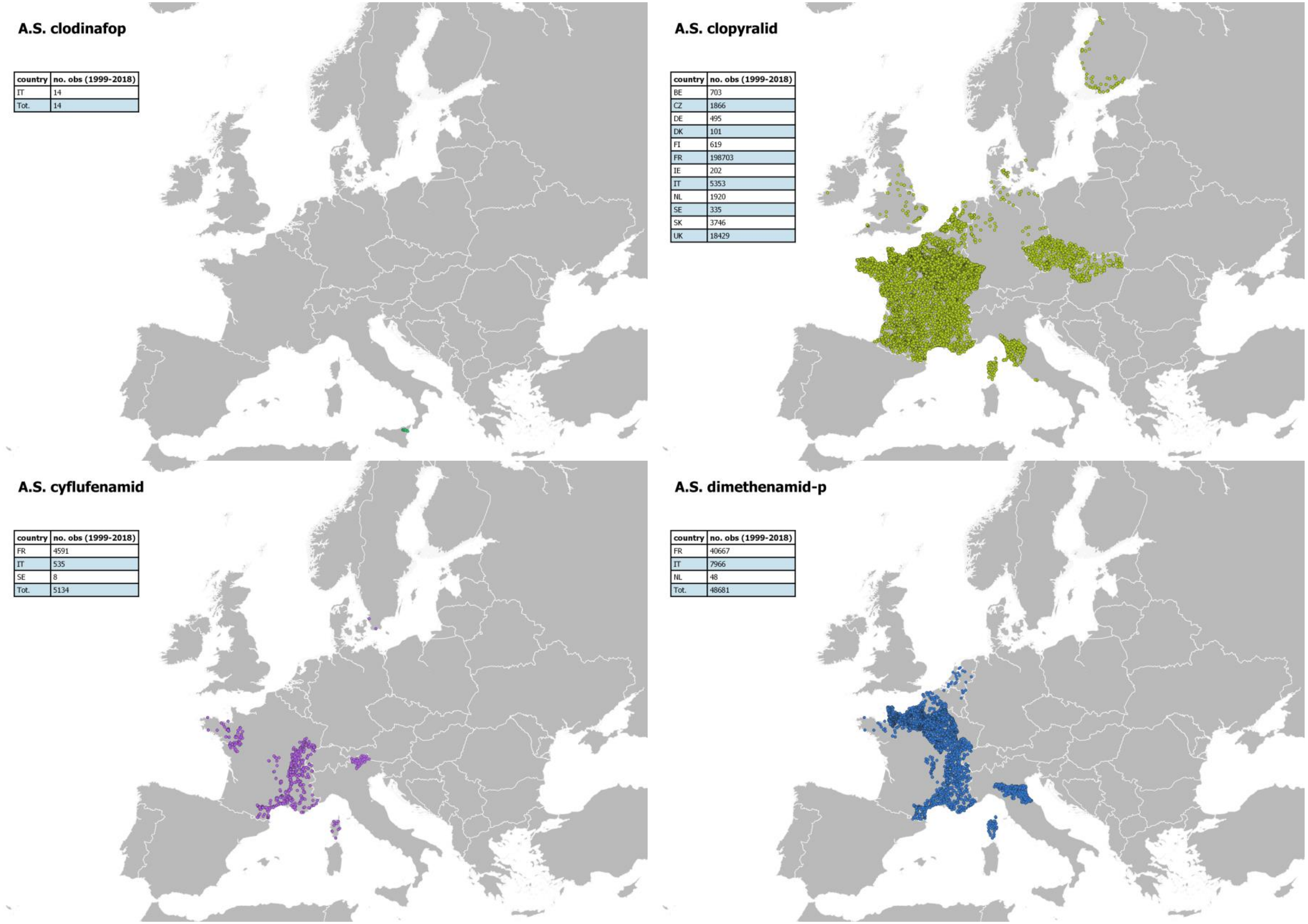

Figure 14- samples available in IPCheM for clodinafop, clopyralid, cyflufenamid, dimethenamid-p

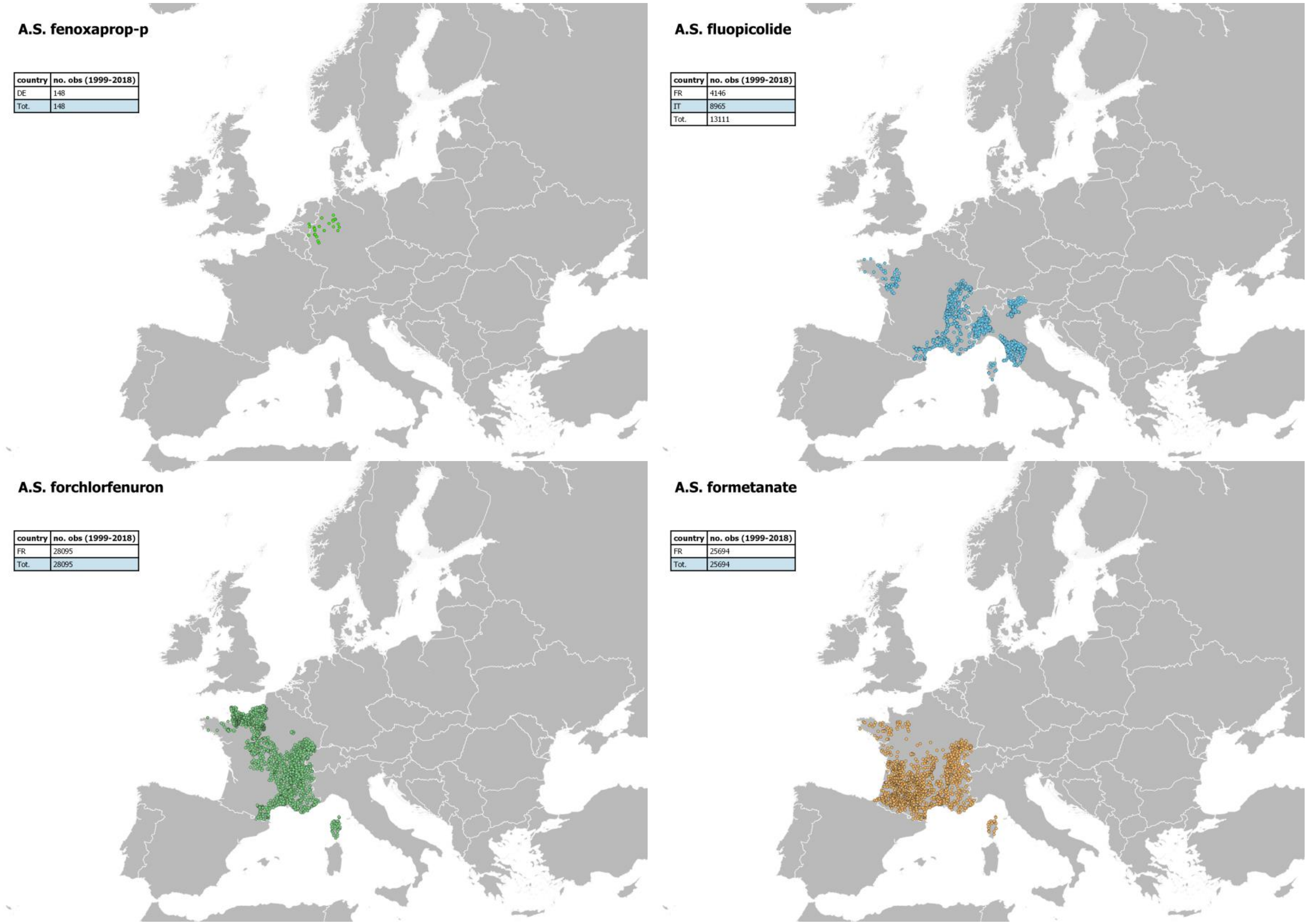

Figure 15- samples available in IPCheM for fenoxaprop-p, fluopicolide, forchlorfenuron, formetanate

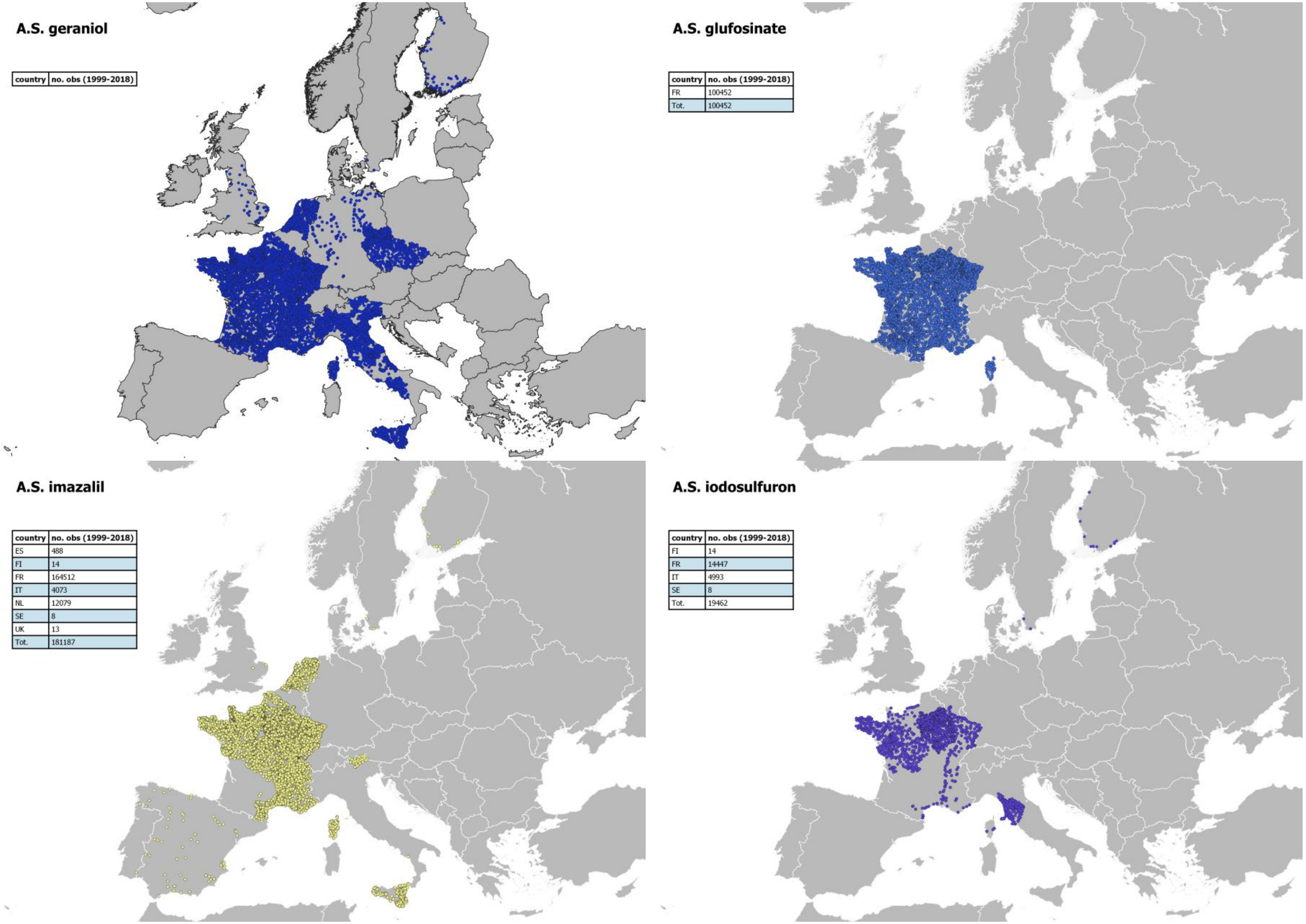

Figure 16- samples available in IPCheM for geraniol, glufosinate, imazalil, iodosulfuron

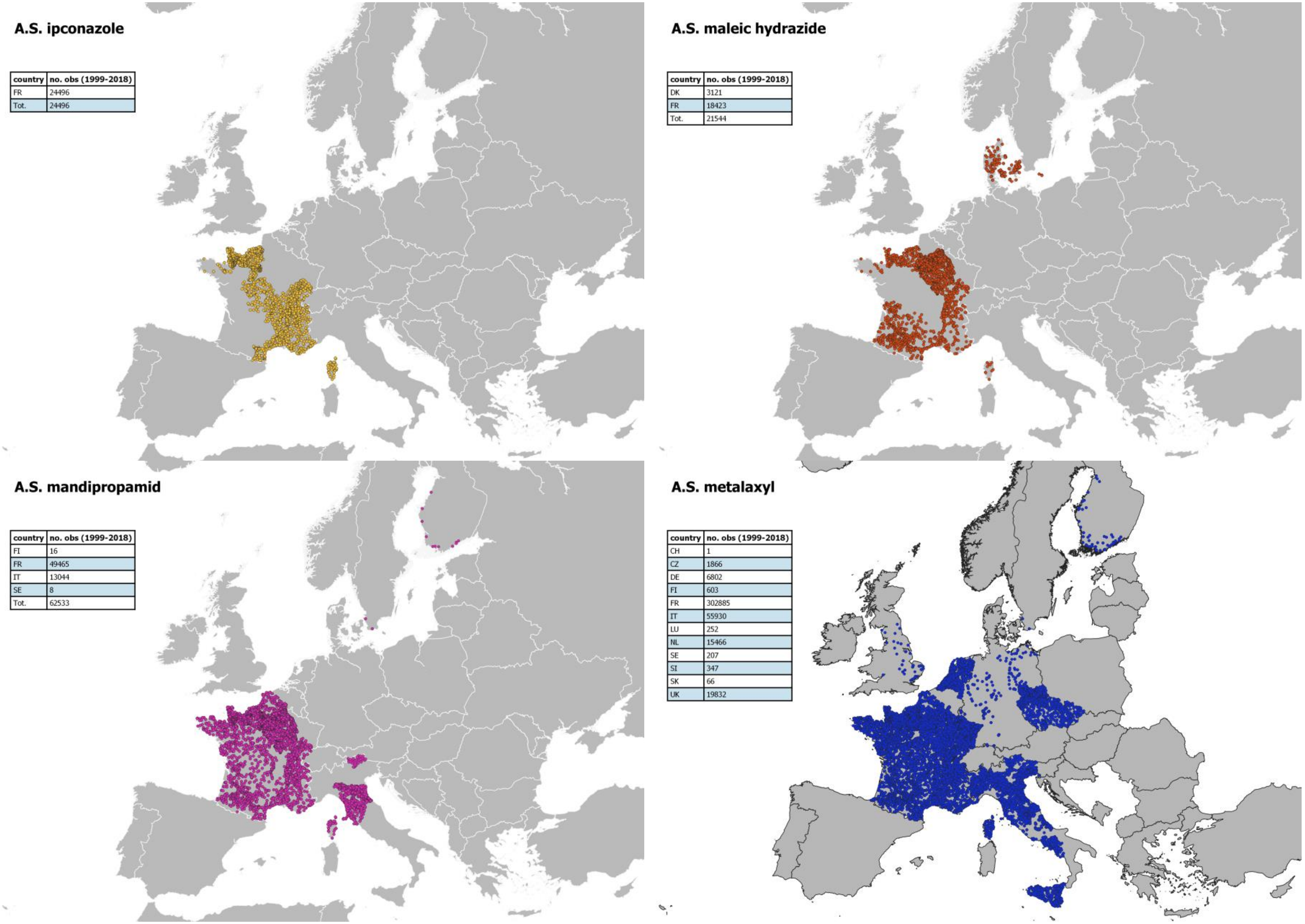

Figure 17- samples available in IPCheM for ipconazole, maleic hydrazide, mandipropamid, metalaxyl

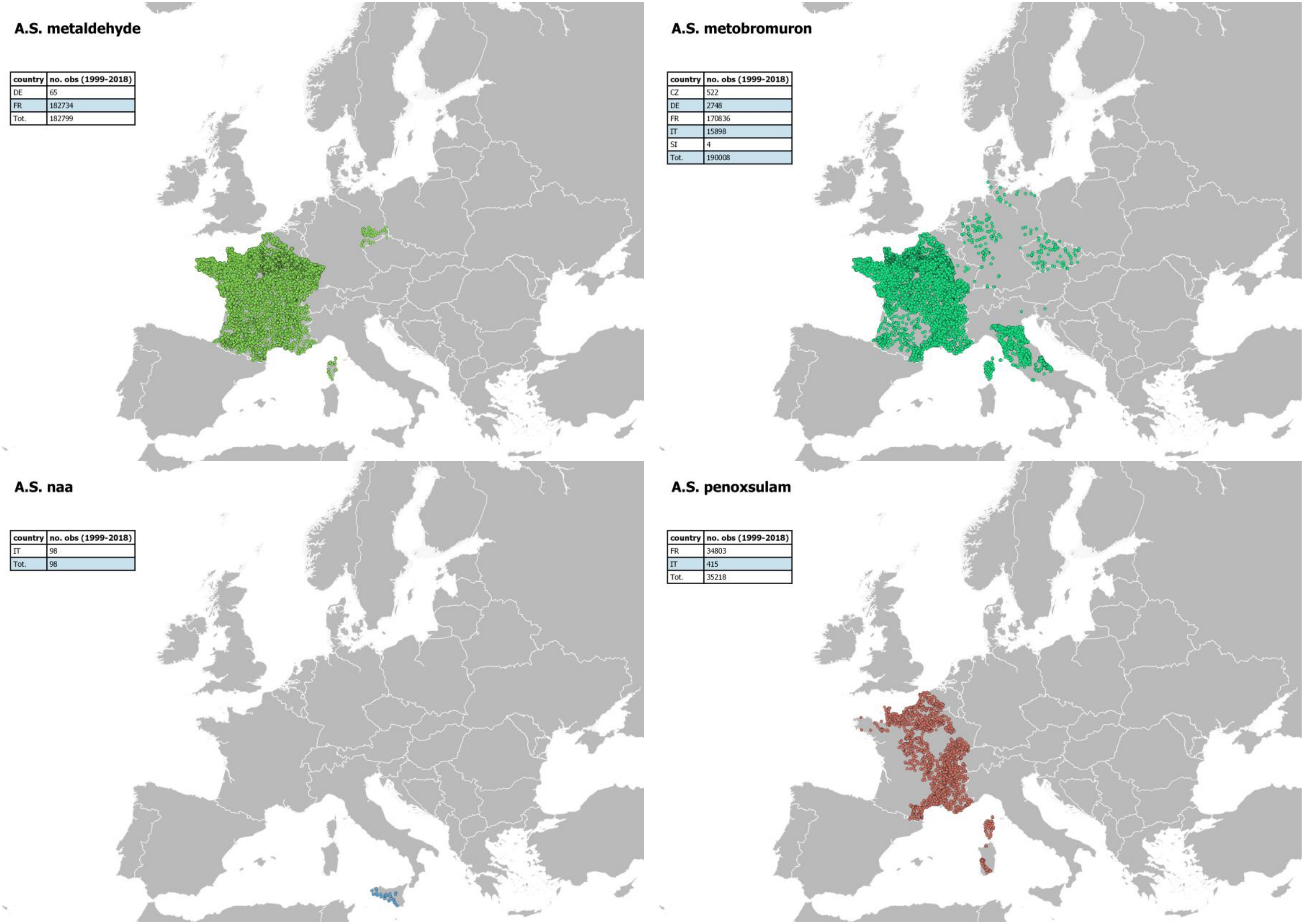

Figure 18 - samples available in IPCheM for metaldehyde, metobromuron, Naphthaleneacetic acid (NAA), penoxsulam

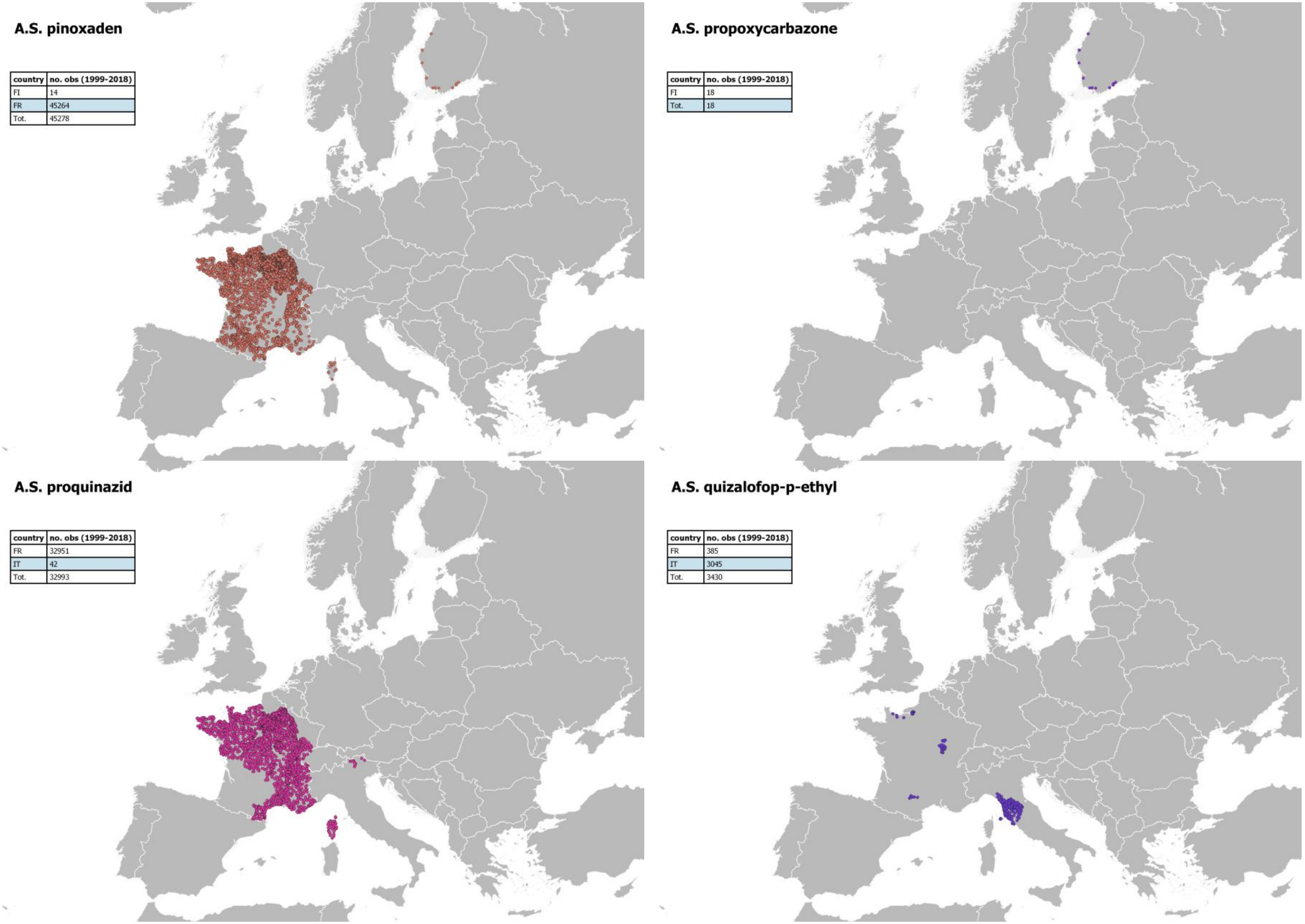

Figure 19 - samples available in IPCheM for pinoxaden, propoxycarbazone, proquinazid, quizalofop-p-ethyl

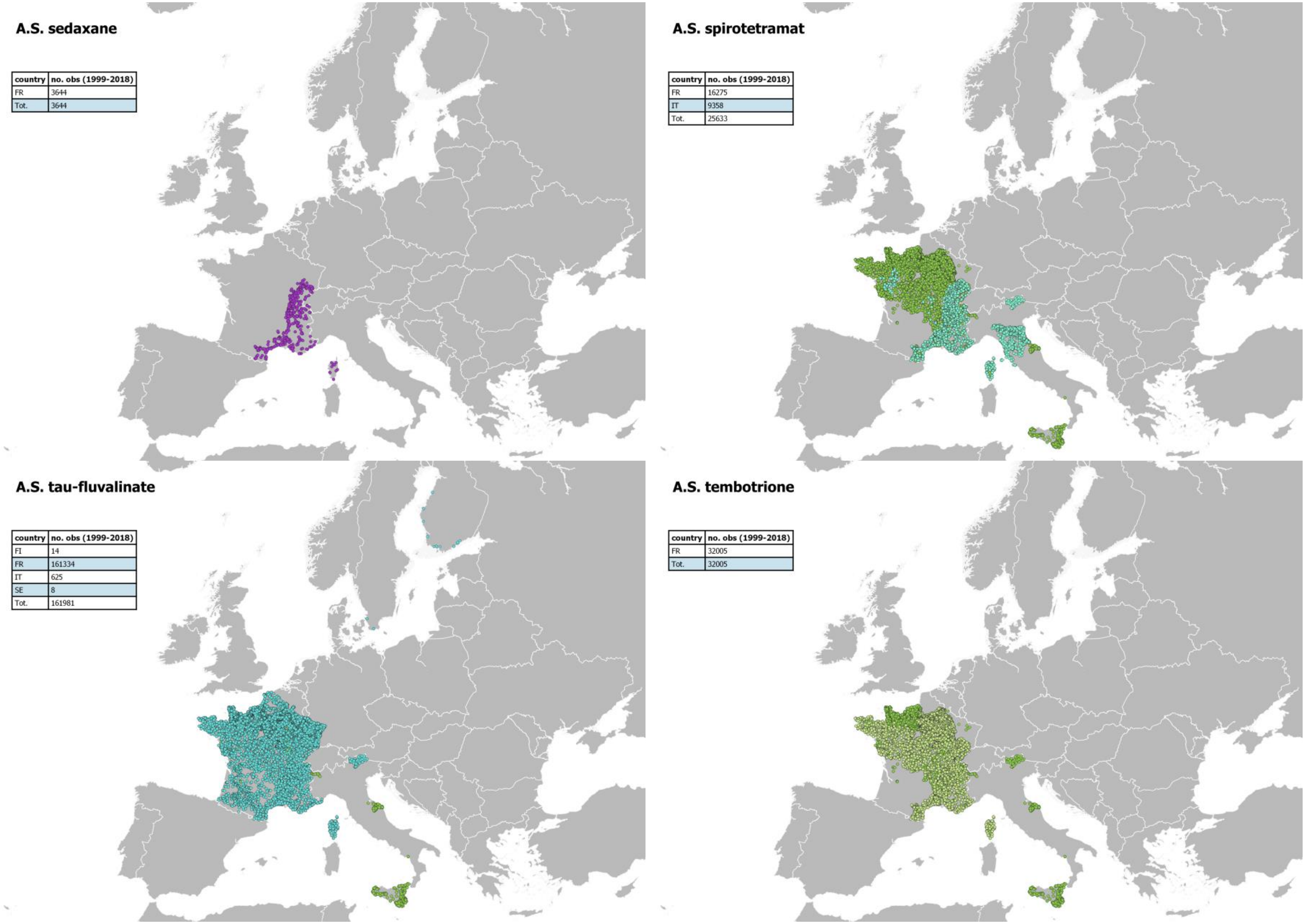

Figure 20- samples available in IPCheM for sedaxane, spirotetramat, tau-fluvalinate, tembotrione.

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