Mapping the Spatial Distribution of Plant Diseases

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Abstract

INEA, inside the TAPAS[1] (Technical Action Plans for Agricultural Statistics) program for the amelioration of agricultural statistics, has developed a methodology based on indirect statistics and, using geographic information system technology, the integration of different data typologies and sources. The production of indirect statistics on the use of pesticides is based on land use data (annual cultivation surfaces) in correlation with Good Agricultural Practice and/or with pesticides national data bank (annual quantity of pesticides per cultivation). The integration of these data with different sources and typologies (industrial production and sales, pesticide costs and uses at farm level, etc.) is essential to correct, calibrate and validate indirect statistics. In particular, FADN (Farm Accountancy Data Network) data, with the definition and the implementation of a specific questionnaire on pesticides use on 100 farms (geographically referenced) FADN sample, are strictly required to define the diffusion of Plant diseases.

Introduction

During the last decade there has been a growing requirement within the European Community for meaningful and accurate statistics on pesticide use. As the environmental indicators grew; explaining also the role of pesticides and their impact on the environment, sound statistical information was required, particularly if the role of policy changes on pesticide use was to be assessed over time.

Furthermore, an important target of the European Commission's 5th Environmental Action Programme is the reduction of pesticide risk, and it will be impossible to monitor without sound information on changes in use over time.

Reductions measured just in volume applied are meaningless with regard to risk, as many new active substances are applied at rates per hectare much lower than the older products that they are replacing, bringing quiet significant reductions in the applications by chemical load, without necessarily resulting in any reduction of use or risk. From this point of view, the accumulation of sales statistics, and the general trends of reductions in load used which they frequently reveal, can be seen to fall a long way, short of providing the type of data required to allow meaningful assessment of the impact of policy changes on pesticide use and their consequences for the environment.

The collection of a reliable set of usage statistics has value in many areas of research, legislation and agricultural support, and should not be seen as a simple statistical exercise in its own right. For more details on the subject see annex 1.

In the last years, through the availability, at EU and national level, of several database on the information about the use of pesticides and to more accessible GIS technologies and data sources, a new methodological approach, based on indirect statistics on the use of pesticides, is going to be developed.

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[1] Following a broad reflection which started at the beginning of the 1990s the Council approved a legal Framework (Decision 96/411/EC, the "TAPAS" Decision) which allows the Commission, in close co-operation with the Member States, to develop and implement, with a Community financial contribution, annual "Technical Action Plans for the improvement of Agricultural Statistics". The TAPAS are defined in close co-operation between the Commission and the Member States within the Framework of the Standing Committee for Agricultural Statistics, established by the Council in 1972.

This methodology allows to develop a system to produce and organise data at geographical level, considering that agri-environmental problems are related to specific areas (environmental vulnerability areas), inside defined boundaries, usually corresponding to river basin. The main tool used is GIS (Geographic Information System) technology that integrate different data typologies and sources (cartographic layers, administrative and statistic data, manuals and data on diseases distribution and pesticides requirements of each crop).

In general, the work shows how it is possible to utilise FADN as part of a statistical project, in particular as indicator/basis to establish the average quantities of utilised pesticides at farm level (amount used or rate of application - kg/ha) to produce indirect statistics about the use of pesticides in agriculture, combining different type of data from different sources.

In this sense FADN data are extremely important (essential for both, diseases distribution and utilised quantities of pesticides data), probably the key element, to produce indirect statistics on the use of pesticides with a territorial approach. FADN could be also useful for identifying the area by plant diseases (or area of crop treated) and the list of crop treated and product used.

In this paper particular attention is paid on the valorisation of FADN network and data to develop geo-spatial distribution map on plant diseases. The Spatial Distribution of Plant Diseases is essential to produce statistics on the use of pesticides, and in the following chapter is described the methodology developed to accomplish this task, and the practical application in a case study.

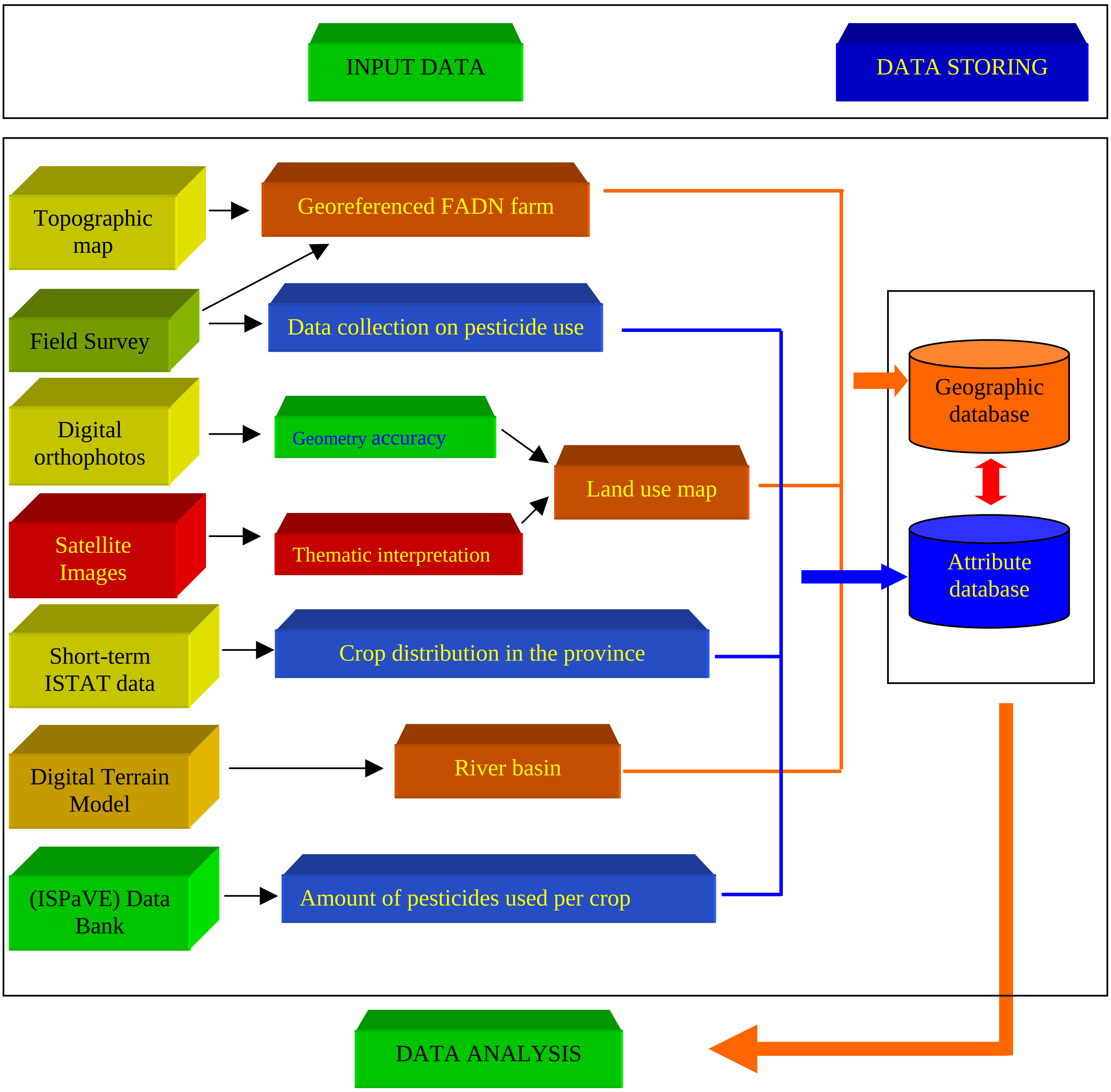
Data and procedures

The methodology is based on the following points:

- Geographic area of reference: a southern province of Italy (level NUTS III);
- CASI 3 Land use map, has been produced by INEA within the 'Water resources' project financed by the National Operative Programme of the Structural Funds. CASI 3 is a cartography layer obtained from satellite images interpretation, (Landsat TM), digitising from digital orthophotos, on grey tones, of geometric resolution of 1 meter pixel, and with a further extension and improvement of the classification system derived from the CORINE Land Cover legend to the IV level for the irrigated classes. For the irrigated classes the acquisition scale was 1:50.000, while for the other classes (urban, woods, waters) the CORINE scale of 1:100.000 was maintained;
- administrative data about the crop distribution in the province, in particular, short-term ISTAT[2] data, have been used and aggregated for Agricultural Region, as for that belonging to the same land use map year (1998);
- data about the amount of pesticides used per crop, in accordance with the 'Good agricultural practices', and the Pesticides Pathology Institute (ISPaVE) Data Bank;
- data about the quantity of pesticides used by the farms, and spreading of the most important diseases on the study area. The data has been collected from the FADN through a particular Technical survey
- building the geographic and alphanumeric database
- utilisation of GIS technology to perform spatial analysis and data aggregation at geographical level (river basin and/or land unit);
- results and data analysis.

[2] National Institute of Statistics

The following flow chart show the general schemas of the work.



Methods and activities

Area of interest

The area of the province of Chieti in the Abruzzo region is the one that has been selected for the realisation of the TAPAS project. This area is characterised by a widest watershed, especially , in this province run the rivers: Trigno, Osento, Sangro e Sinello, that form important river basins.

The province total area is about 258.648,42 hectares, of which 145,86 He have the land-use (table 1) represented by the classes obtained from Casi 3 cartography (where crop classes are appositely aggregated for the project object).

Land use re-interpretation

The estimation of the statistics about the use of pesticides in agriculture is relevant to know land use of the study area on a level suitable to distinguish the single cultural species.

Using CASI 3 cartography the project area has been interpreted to a detailed level that allowed making such a distinction.

In order to re-construct the land use, a defined procedure has been followed integrating data from different sources (geographic and administrative/land unit) following these steps:

- intersection between CASI 3 land use map layer and the Agriculture Regions layer;
- aggregation and definition and sum of the areas according with the CASI 3 classification and short term ISTAT data for single Agriculture Region;
- calibration of the ISTAT data with the CASI 3 data;
- identification of the possible frequency classes of the different crops growing inside of each CASI 3 class polygon. (i.e. a 30 hectares polygon, formed by land suitable for irrigation of industrial crops class 2121, is made by: 45% corn, 20% sugar beet, 15% sunflower, 10% sorghum = 100%). You can get through this each single crop's area for every agricultural Region;

Table 1 Agricultural distribution of the Chieti Province area

Land cover classes			Hectares
Code		Description	
211	-	Cereals (not corn)	62.786
2121	-	Industrial Crops	2.739
2122	-	Autumn vegetables	1.979
2123	-	Summer vegetables	1.816
221	-	Vineyards	30.215
223	-	Olive	42.285
222	-	Orchards	3.807

(INEA - Land use map, CASI 3)

Pesticides Data-bank

This data bank has been provided by ISPaVe Institute and has the suggested optimal quantities for each culture, of the different pesticides, to be used depending on the found diseases.

Used quantities on farms and disease diffusion.

Furthermore the ongoing data survey on the FADN farms, research studies has been done with the ARSSA Institute (Plant disease observatory) especially on the diffusion of the diseases.

The results are summarised in the chart below:

Table 5.2 Main deseases on FADN sample

Crop	Pathology (Latin and Italian name)

Vineyards	Peronospora - Oidio - Botrite
Olive trees	Mosca delle olive - Occhio di pavone
Peaches	Bolla del Pesco - Oidio - Cancri rameali - Monilia - Corineo - Cidia - Anarsia - Cocciniglia bianca - Tripidi - Afide verde
Tomatoes p.c.	Peronospora - Botritis - Alternariosi - Oidio
Tomatoes c.p.	Peronospora - Botritis - Cladosporiosi - Alternariosi - Oidio
Tobacco	Peronospora - Pulce
Cereals	Oidio - Ruggini

Source: ARSSA - OMP 'Technical guidelines for plant protection', reg. Cee 2078/92.

Table 1 – Main diseases on FADN sample

Culture	Pathology (Latin name)									
Vineyards	Peronospora	Oidio	botrite							
Olive trees	Mosca delle olive	Occhio di pavone								
Peaches	Bolla del Pesco	Oidio	Cancri rameali	Monilia	Corineo	Cidia	Anarsia	Cocciniglia bianca	Tripidi	Afide verde
Tomatoes p.c.	Peronospora	Botritis	Alternariosi	Oidio						
Tomatoes c.p.	Peronospora	Botritis	cladosporiosi	Alternariosi	Oidio					
Tobacco	Peronospora	Pulce								
Cereals	Oidio	Ruggini								

Source: ARSSA - *OMP "Technical guidelines for plant protection", reg. Cee 2078/92*

Data analysis

The data analysis steps have been done through these phases:

- Geographic intersection between the Agricultural region and the CASI 3 Land use layers, to obtain a resulting a vector layer where Land codes each polygon. Aggregation of the Land use data by A.R.
- ISTAT data calibration aggregated by A.R., with CASI 3 land use data, with specification for each polygon of the possible frequency classes, of the different cultures. Pesticides mapping of the most spread diseases in the regional area using the following procedure:

Methodology used in the spatial distribution of Plant diseas Mapping

1. Using the FADN farms sample, a vector point layer has been created , divided in two categories:

- ❑ Vineyard - Olive grove farms (most important crop in study area)
- ❑ Orchard and arable land farms

each of these farms sample has been coded regarding the disease observed during the farm survey, using the code number table illustrated below;

P1 = Plasmopora viticola (vineyard)

P2 = Uncicola Necator (vineyard)

P3 = Lobesia Botrana (vineyard)

P4 = Dacus oleae (olive grove)

P5 = Mycosis various (olive grove)

P6 = Infesting vineyard + olive grove

P7 = Mycosis various (Orchard)

P8 = Insect various (Orchard)

P9 = Infesting (Orchard)

P10 = Mycosis various (Arable land)

P11 = Insect various (Arable land)

P12 = Infesting (Arable land)

In figure 1 is showed the point shape file *Rica_farm_sample* and related attribute table, inside an ArcGis view.

The structure of the code used (field P1……..P2) is a Boolean type.

0 = absence of disease or infestant

1= presence of desease or infestant

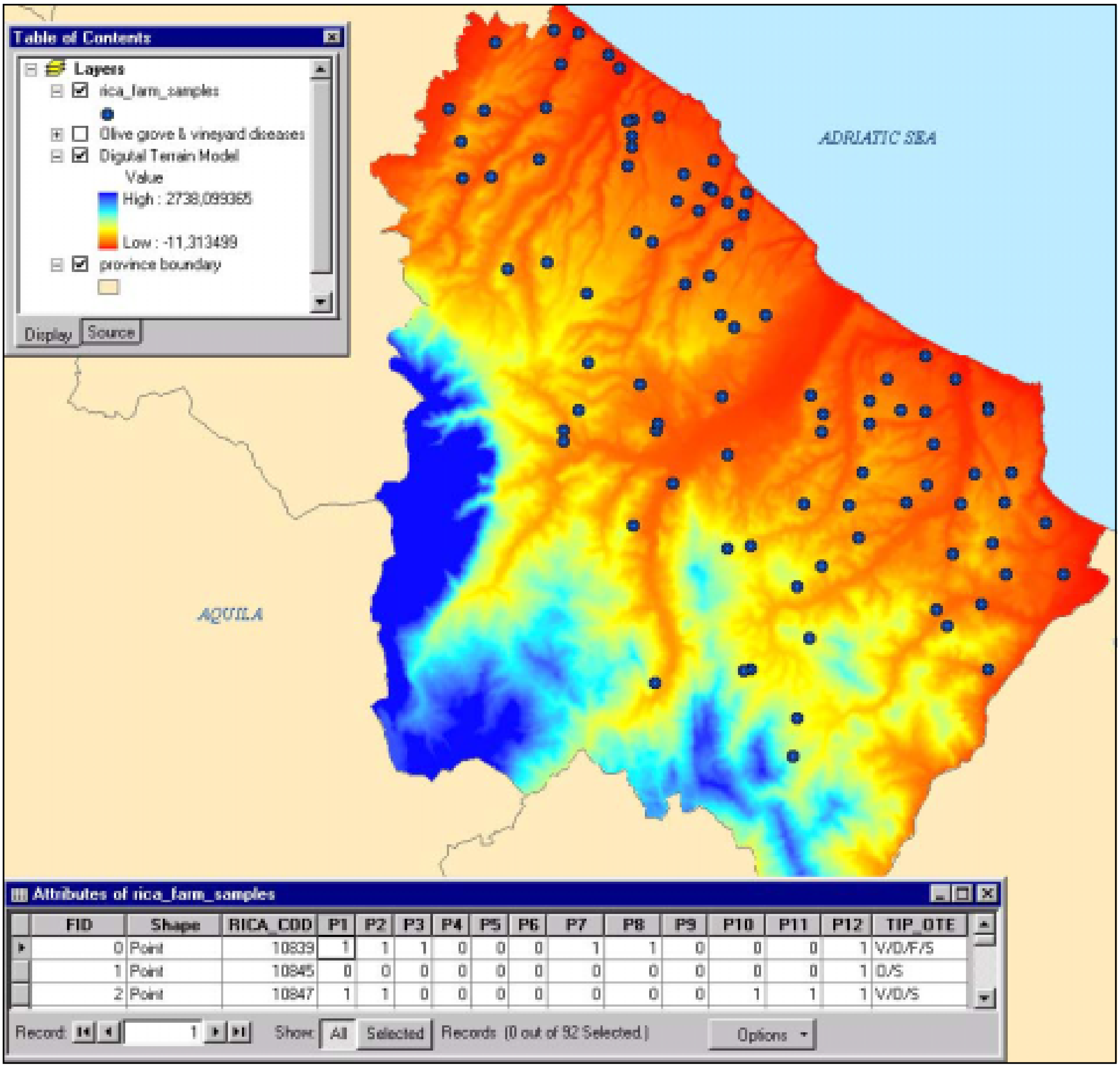


Figure 1 - FADN sample distribution inside the study area

2. Next step has been the interpolation between the sample point to obtain a predict value for unknown location.

Among the different interpolating techniques - stands the few sample points - we choose the Inverse Distance Weighted (IDW) method, that is a simple interpolation techniques that can often yield satisfactory results. The basic premise of inverse distance is that data points are weighted by the inverse of their distance to the estimation point. This approach has the effect of giving more influence to nearby data points than those farther away. Additionally, the inverted distance weight can be raised to further reduce the effect of data points located farther away. This approach is mathematically expressed as:

$$v_0 = \frac{\sum_{i=1}^{N(v_0)} \frac{1}{d_i^p} v_i}{\sum_{i=1}^{Nv_0} d_i^p}$$

where:

v_0 is the estimated value at (x_0, y_0),

v_i is a neighbouring data value at (x_i, y_i),

d_i is the distance between (x_0,y_0) and (x_i,y_i),

p is the power

$N(v_0)$ is the number of data points in the neighbourhood of v_0.

3. Therefore trough the interpolation process, 12 different layers have been created (in GRID format with a 100 meter resolution) for each code number;

4. The obtained layers have been summarised into two final grid layers (one for the olive grove and vineyard – code P1, P6 and the other one for the disease distribution for Orchard and Arable land disease distribution code P7, P12); the grid summarising "need to compute an offset that will scale each grid so they are added together without overlapping cell value".[3] To compute the offset following map calculator has been used, scaling the different grid by a power of 10:

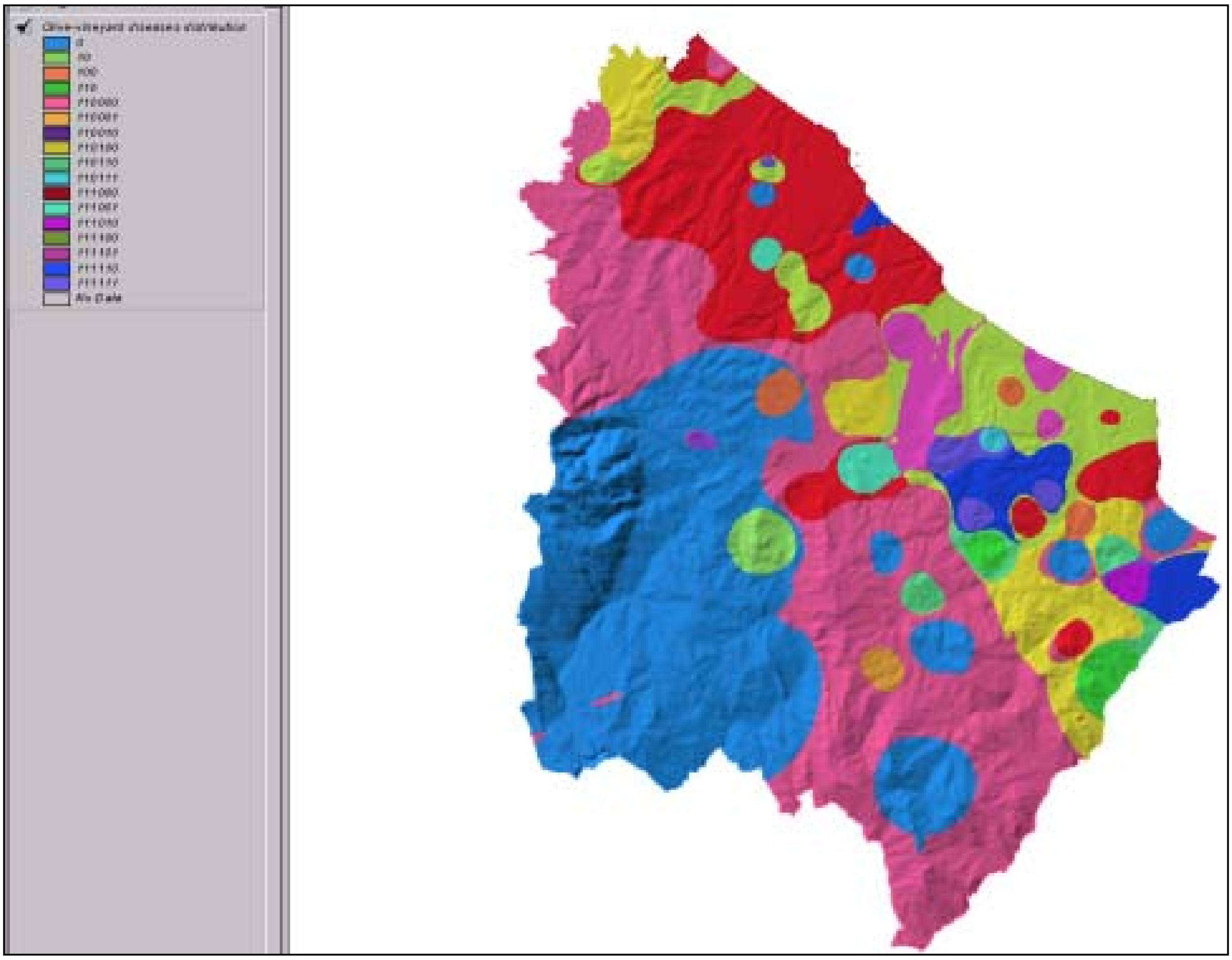
$$NewGrid = (GridP1 * 10) + (GridP2 * 10) + ...(GridPn)$$

Grid P1					Grid P2					Summarise P1 P2				Legenda
1	0	1	1		0	0	1	1		10	00	11	11	00 = no disease
1	1	0	0	+	0	1	0	0	=	10	11	00	00	10 = presence of Plasmopora
0	0	1	0		0	0	1	1		00	00	11	01	01 = presence of Uncicola Necator
1	1	0	1		1	0	1	1		11	10	01	11	11 = presence of both Plasmopora and Uncicola

Table - example of grid summarising

Figure 2, illustrated the results of the grid summarising related to vineyard and olive grove diseases distribution.

[3] Peter J. Ersts - *Summarise information between grid* - *ArcUser Magazine,* Vol. 4 N. 4, October - December 2001



5. The Grid layer has been converted into a vector layer, which has been intersected with the land use cover, thus obtaining for each polygon the information about the different type of disease found;

6. Using the surveyed farms data about the pesticides quantities used on the farms and those from best practices data (ISPaVE) a JOIN table has been created which has been linked with Land use-disease diffusion vector layer table, getting in this way the average quantity used for each polygon;

7. Calculating and dividing alphanumeric data regarding the Fungicide, Insecticide and Herbicide total quantities in two categories:
    - Data obtained from the farms data survey;
    - Data obtained from the best practice data.

The difference between the two sets of data has been calculated.

Furthermore the Land use/disease diffusion vector layer has been intersected with the river basin layer to get the total quantities of pesticide used for river basin.

Results and conclusions

The achieved goals are both, geographical and statistical.

The geographical part is made by the following data:

- Cartography representing plant diseases distribution (on the basis of FADN surveys);
- Cartography representing quantities calculated for each polygon based on ISPaVE data (quantity suggested);
- Cartography representing quantities calculated for each polygon based on FADN data (quantity used on farm);
- Cartography representing the differences between the two above;
- Data aggregation for river basin of the area (obtained from Digital Terrain Model analysis in Arc Info environment).

The statistical part is made by the following data reports:

- Pesticides quantities for the main categories calculated at NUTS III and river basin level
- Definition of correction factor between agricultural best practices quantities and pesticides real use at farm level (main problem for indirect statistics)
- Comparison with data on sales at NUTS III level, to test the possibilities to use administrative data.

Table 5.3 Summary and comparison on the used quantities (Quintals) of pesticides - Year 2001- NUTS III (Provincia di Chieti)

Pesticide typologies	recommended/optimal quantities	effective quantities used by FADN farms
Insecticide	276.26	437.66
Fungicide	3.262.65	4.872.39
Herbicide	229.48	230.17

Developing the indirect statistics methodology, the greatest problem was the lack of data on diseases distribution. This data is essential to produce indirect statistics on the basis of pesticides recommended quantities of Good Agricultural Practice and/or pesticides national data bank. In fact, we should consider each disease as always present in the area (NUTS III or river basin). FADN data are essential to calculate both the diseases distribution and the utilised quantities of pesticides data. The access to FADN data on the real use of pesticides could be the key element to apply an indirect statistics methodology with a good costs-benefits ratio. Therefore it is strictly recommended to make data surveys with the implementation of a questionnaire on the use of pesticides.

In conclusion:

- FADN could allow to produce indirect statistics on the use of pesticides and on other agri-environment aspects, integrating different data sources (GIS) with a good cost-benefit ratio and accuracy;
- FADN data are strictly required to define the diffusion of plant diseases and the specific dosage per hectare effectively used in each area;
- on the basis of the actual data set, is still not possible to define automatic procedures realising indirect statistics on the use of pesticides;
- as for the majority of IDSS, the filter and the interpretation of data from a thematic senior specialist, supported by orthophotos, satellite image and ancillary data, is strictly recommended.

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Annex 1 Role of Usage Statistics on Pesticides

In their simplest form, usage statistics provide information on national and regional levels of pesticide inputs to individual crops. Thus the total amount of any one pesticide used annually should be available, together with the areas treated and the range of crops to which it has been applied. Additionally, information on the total inputs of all pesticides to any one crop would also be available. Both these may be broken down to provide a seasonal profile of use, as dates of application should also be available. Such data are required at several levels.

Usage data are critical for the development of indicators of the effects of pesticides on the environment, and data sets over time are required in order to monitor the effects that policy changes may have on that impact. Programmes within the EU (Sectoral Infrastructure Projects in the Context of Environmental Indicators and Green Accounting) and OECD (Pesticide Forum: Pesticide Risk Reduction Project) are acutely aware of the necessity for sound usage data over time in order to fully develop such indicators.

Once the collection of a regular set of usage statistics has been established, changes over time in use on particular crops, or of particular pesticides, can be monitored. These may result from several factors, some or all of which may interact to give annual variations in use.

Data on pesticide usage can be used to assist in the monitoring of pesticide contamination in surface and ground waters. Fro example, the EU aims to protect drinking water and groundwater through legislation, leading to widespread monitoring of pesticide residues in order to comply with these directives. Within Great Britain, usage data are used within a complex geographical information system, containing maps of soil and groundwater, rivers and other waterways and water abstraction points. This is overlaid with current cropping and pesticide usage patterns, both geographically and seasonally, and, together with a database of pesticide properties and models of movement through different soils, is used to predict the likely appearance of pesticides at abstraction points to facilitate the monitoring of pesticides in water. By so doing, it is hoped to avoid unnecessary monitoring for pesticides which are unlikely to appear at a specific point or time within a given water body. It is important to note, however, that such methods can only be used to direct monitoring rather than substitute for it.

Data on farmers' actual use of pesticides may be examined to see their current practices may be improved or optimised. For example, within Great Britain, the comprehensive database of farmer practice with regard to fungicide and insecticide use on winter wheat is being examined to identify where farmers may be using pesticide programmes inappropriately. This is being examined particularly with regard to under-utilising varietal resistance or inappropriately timed pesticide applications. Furthermore, there would appear to be some scope for reducing pesticide applications under certain circumstances. It is hoped that areas where clear savings can be made will be identified and targeted for further advice, in an effort to reduce inputs of pesticides to those crops. The technique should be applicable to many crops.

Annex 2 Use of pesticides (Kg) per river basins in Chieti Province, according to FDN data and recommended quantities (pesticides national data bank)

RIVER BASIN NAME	TOTAL PESTICIDES		
	(A) FADN	(B) Recommended quantities	Difference (A - B)
Alento	210.551,95	138.700,83	71.851,12
Arielli	2.034.517,20	1.303.495,24	731.021,96
Feltrino	1.041.390,28	668.790,39	372.599,89
Foro	430.702,16	276.222,54	154.479,62
Moro	2171.733,96	1.394.009,48	777.724,48
Osento	84.784,11	72.074,76	12.709,35
Sangro	110.894,65	91.413,50	19.481,15
Sinello	131.740,55	111.774,33	16.813,06
ZL tra Moro e Feltrino	1.345,65	13.39,47	6,18
ZL tra Sangro e Osento	12.378,74	10.938,34	1.440,40
ZL tra Sinello e Trigno	45.554,00	36.946,81	8.607,19
ZL tra Arielli e Moro	286.939,82	183.829,29	103.110,53
ZL tra Feltrino e Sangro	21.497,92	15.435,18	6.062,74
ZL tra Osento e Sinello	85.508,59	56.809,12	28.699,47
TOTAL BASINS (Kg)	**6.717.040,95**	**4.392.467,59**	**2.324.573,36**
TOTAL BASINS (Ql)	**67.170,41**	**43.924,68**	**23.245,73**