ENDURE

European Network for Durable Exploitation of crop protection strategies

Project number: 031499

Network of Excellence
Sixth Framework Programme

Thematic Priority 5
FOOD and Quality and Safety

Deliverable DR3.2

Economic Analysis of Plant Protection Strategies for two Case Study Crops in four EU Regions

Due date of deliverable: M18

Actual submission date: M18

Start date of the project: January 1st, 2007 **Duration**: 48 months

Organisation name of lead contractor: AGROS

Revision: V1

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)	
Dissemination Level	
PU Public	
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	**X**

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Abbreviations

AT	Austria	**DE**	Germany	**NL**	Netherlands
BE	Belgium	**GR**	Greece	**PL**	Poland
BG	Bulgaria	**HU**	Hungary	**PT**	Portugal
CY	Cyprus	**IE**	Ireland	**RO**	Romania
CZ	Czech Republic	**IT**	Italy	**SK**	Slovakia
DK	Denmark	**LV**	Latvia	**SI**	Slovenia
EE	Estonia	**LT**	Lithuania	**ES**	Spain
FI	Finland	**LU**	Luxembourg	**SE**	Sweden
FR	France	**MT**	Malta	**UK**	United Kingdom

ART	Agroscope Reckenholz – Tänikon
AS	Active Substance / Active Ingredient
EPPO	European and Mediterranean Plant Protection Organisations
EC	European Commission
ENDURE	European Network for Exploitation of Durable Crop Protection Strategies
EU	European Union
EOS	Experts opinion survey
ZMP	German center for information of markets and prices of agricultural and forestry commodities and food
IP	Integrated Production
IOBC	International Organisation for Biological and Integrated Control of Noxious Animals and Plants
Kg AS/ha	Kilograms of Active Substance per Hectare
NPIC	National Pesticide Information Center of the United States
OF	Organic Farming
PAN	Pesticide Action Network
PMR	Pesticide Movement Rating
WS	Water Solubility

Abstract

An analysis of economic driving forces is carried out to identify and improve the implementation of crop protection strategies that rely less on pesticide use and are still economically feasible. The analysis is divided in three phases: First a classification of agricultural systems currently implemented in the EU for wheat and apple production according with two dimensions of pesticide use, the intensity and the innovation, is conducted. Then, socio-economic factors that influence pesticide use intensity and innovation will be identified on farm level and under defined policy scenarios and in addition the profitability of crop protection strategies will be calculated. Finally, policy recommendations will be made to foment those factors that make possible economically viable crop productions that are less dependable on use of pesticides.
This report deals with the first part of the economic analysis.

The proposed classification of agricultural systems is based on the use of inputs (more than a farm management strategies classification) to address crop protection strategies that rely less on use of pesticides. The two indicators of pesticide use are complementary. Intensity is equal to the quantities applied, while innovation encloses the properties and characteristics of the products applied. The obtained classification indicates in which countries similar crop protection strategies are currently implemented.

For both cereals and fruit trees we have found that the use of pesticides at high intensity levels is associated with higher crop productivity, as well there is evidences that in traditional and modern farming, the productivity is boosted with increments of the area under production. This fact can suggest some type of specialisation in the production. Similarly, the results confirm that crop yields associated to agricultural systems characterised by low pesticide intensity might be comparable in absolute quantities to those yields obtained under other systems, if the area under production is augmented.

From the classification of agricultural systems that are currently implemented in production of fruit trees in Europe, it is possible to conclude that the evolution in crop protection is focused on the use of pesticide products that are potentially less hazardous, as the modern farming and the eco-friendly agriculture are the most important systems in terms of area under production, crop production and number of countries included.

However, the current tendency in terms of areas under production and quantity of wheat and apple produced is dominated by cropping systems categorised within the higher level of pesticide innovation. It is also remarkable that in wheat and apple productions characterised by lower pesticide use intensity, the crop protection costs show a decreasing trend when the pesticide use innovation is increased.

The results show that for the production of wheat and apple, there are three facts that coincide in this economical analysis:

- Higher revenues are obtained under production schemes characterised by high intensity in pesticide use (i.e. traditional and modern farming).
- For productions characterised by low intensity in pesticide use, the relative costs of crop protection products are lower, if the level of pesticide use innovation is high (i.e. lower relative costs of crop protection products under eco-friendly agriculture than under extensive agriculture).
- Expenditures in crop protection represent a larger percentage within the crop production costs in modern farming than in traditional farming.

Economic Analysis of Plant Protection Strategies for two Case Study Crops in four EU Regions

1. Introduction

With this economic analysis, Agroscope Reckenholz - Tänikon (ART) contributes to the objectives of the European Network for Exploitation of Durable Crop Protection Strategies (ENDURE), and specifically in the development and implementation of sustainable crop protection strategies.

This economic analysis consist of three parts:

(1) The description and evaluation of the profitability of different crop protection methods that are currently implemented in different European countries.
(2) The identification and quantification of socio-economic driving forces related to these different crop protection methods and the explanation of the developments of these different plant protection strategies by establishing causal relations between socio-economic factors and pesticide use intensity and innovation.
(3) The recommendation of policy measures to improve the adoption of sustainable agricultural practices by fomenting those socio-economic factors that reduce dependence on use of pesticides and ensure that these plant protection strategies are still being profitable.

This report deals with the first section of the economic analysis, the description and economic valuation of plant protection strategies. The report includes three sections:

(a) A classification of agricultural systems and plant protection strategies that are applied in cereal and pomefruit production, according with two particular attributes of pesticide use: intensity and innovation.

(b) An evaluation of the sustainability of these crop protection strategies from an economic point of view by estimating selected profitability indicators.

(c) A selection of one representative case study region for each plant protection strategy, where the economic analyses on farm level and under defined policy scenarios will be performed during the execution of the second phase of ENDURE (between July 2008 and June 2009).

The classification and economic evaluation of crop protection strategies in different European countries are an essential precondition to identify and quantify socio-economic driving forces and give policy recommendations. On the basis of the results of the classification four European regions are selected, which are different in terms of pesticide intensity and pesticide innovation. For these four regions economic driving forces on pesticide use will be studied.

Section A. Classification of Agricultural Systems

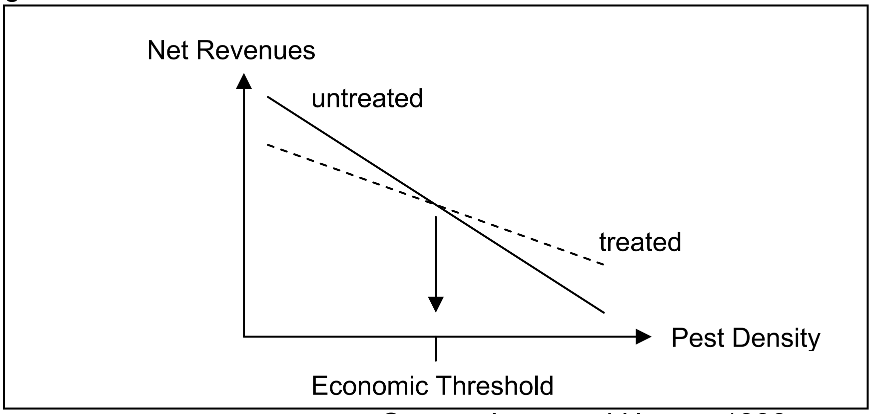
2. Problem Setting

The legislation related to the use of pesticides in agriculture in the European Union (EU) aims to set specific conditions on the placing of pesticides on the market (Directive 91/414/EEC), to establish maximum residue levels tolerated on food and feed (Directive 86/362/EEC and Directive 90/642/EEC) and to achieve a sustainable use of pesticides (Com (2002)349).

Specifically within the sixth environmental action programme of the European Commission (EC) a thematic strategy on sustainable use of pesticides was elaborated. This thematic strategy has as one of its five main purposes the promotion and implementation of low-input or pesticide-free crop farming, which enclose the concepts of integrated production (IP) and organic farming (OF).

The achievement of this specific objective in crop protection is based on the understanding of ecology of crops, pests, weeds and diseases. The establishing of economic thresholds or levels of occurrence of pests, diseases or weeds, at which the net revenue derived from spraying pesticides is equal to the net revenue resulting from not spraying, (in the Figure 1, the economic threshold for a level of pest infestation is illustrated); and ensuring that pesticides are only applied in the case that their use is needed, as they come out to be more effective than non-chemical measures of control (Luna and House, 1990).

Figure 1. Economic threshold



Source: Luna and House, 1990

Crop protection strategies in IP follow three sequential principles: (1) The prevention of pests, diseases and weeds occurrence through optimal use of natural resources (e.g. using local adapted varieties), appropriate crop management (e.g. estimating nutrient requirements) and protection of beneficial organisms; (2) The monitoring of the occurrence of pests, diseases and weeds and assessing crop loss risks to make a more asserted decision about application of direct controls; (3) and direct intervention by giving priority to natural, cultural, biological, genetic and bio-technical methods over use of pesticides and ensuring in the case that pesticides should be applied that the products used are the most selective, least toxic and least persistent available (Boller et al., 1999).

Thus, it could be expected that the needs and use of pesticides would be reduced when adopting IP. However, it does not necessarily imply that always less quantity of chemical products (in absolute terms) are applied, when comparing with crop protection actions under other cropping systems. For example, it was found that in 1997 the average dose in apple

production in Lerida, ES was 27 kg active substance (AS) per hectare under conventional farming, while in Trentino, IT was 33.5 kg AS/ha under IP (Geier et al., 2001). It is important to remark that these two regions are classified under the same climatic conditions, Mediterranean Zone, but there are other conditions such as soil properties, crop management strategies and biology of pests that determine pesticide needs (Bouma, 2005).

Furthermore, there are empirical evidences that the amount of pesticides required and actually applied to reduce losses in crop production may vary not only among, but also within regions where uniform weather and soil conditions prevail (see EC, 1996). These variations may be attributed to differences in pest control strategies (e.g. diverse crop rotation systems), characteristics of pesticide products (e.g. contact or systemic fungicides) and pesticide effectiveness, which depends on a multitude of factors such as climatic conditions, type of crops, type of pests, pest incidence and resistance, trend in use of pesticides and type of pesticides (Radcliffe, 2002).

Hence, to enhance the accuracy of conclusions and to address more precisely recommendations towards improving implementation of sustainable crop protection methods that are less depending on pesticide use, a classification of agricultural production systems based on the use of inputs is considered as appropriate. Therefore, in this study a cropping system classification through assessment of pesticide use in terms of intensity and innovation is performed.

3. Methodology

An explorative analysis for all European countries is carried out to compare the current performance of crop protection strategies throughout Europe in wheat and pomefruit production. Therefore four *agricultural systems* are defined by two indicators: P*esticide use* intensity and pesticide use innovation. In the following chapters the indicators are defined.

3.1. Definitions

3.1.1. Agricultural Systems

Agricultural production systems could be classified according with their crop management strategies, production methods and use of inputs. The classification shows how the production inputs and factors are related and how they are managed. One of the most common classification of cropping systems according to management strategies includes three categories: conventional, integrated and organic agricultural production. Obviously, the crop protection strategies applied under one specific agricultural system are defined by the characteristics and requirements of that system.

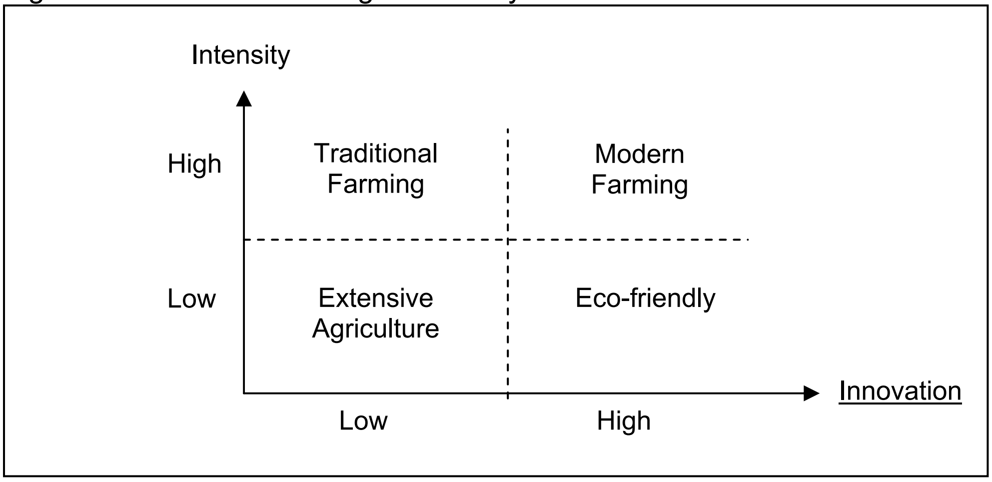
Along with the rapid growth of population in the 1960s the agricultural production experienced a specialization aimed at meeting the consequently increased food needs through high-intensity in use of agricultural inputs such as pesticides and chemical fertilizers. This experience is known as the “green revolution” and also corresponds to a period when the crop yields were evidently increased, even where the productive factors land and labour were limited (Tilman, 1998). This type of production is called **traditional farming** and represents the system that is placed in the upper-left quadrant of Figure 2.

After some years of increased productivity, the revenues associated to traditional farming diminished and for this reason, the production systems were criticized. Furthermore, negative effects on the environment and human health were discussed. That decreasing productivity was understood among others as a logical consequence of the development of pest resistances to chemical inputs and the detriment of natural factors that are involved in crop production, which may be confirmed with the reduction of soil fertility levels. Then, alternative practices (e.g. regular change of products, addition of manure to soil, etc.) were introduced to overtake those problems in crop production while maintaining elevated crop yields. Within this new schema of production, chemical pesticides and fertilizer continued to be used in a high-intensity level (idem). This crop production method is defined as **modern farming** and corresponds to the system that is positioned in the upper-right quadrant of Figure 2.

Low-intensity farming systems include practices, in which the use of agricultural inputs are to some extent reduced, probably influenced by the application of improved farm management strategies, as for example the estimation of fertilization needs based on nutrient balances or precision agriculture, and also systems of crop production that are specifically oriented to minimize the use of synthetic agricultural inputs such as fertilizers and pesticides with the main objective of protecting the environment (O'Connell, 1990).

Although, the application of improved cropping practices enables the optimisation in the use of agricultural inputs, crop yields associated with low-intensity farming systems are normally lower than those obtained under traditional or modern farming systems and in consequence, the commercial capability is directly associated with the use of large areas of production. For that reason, this system of crop production is often called **extensive agriculture** and is identified with the farming method placed in the lower-left quadrant of Figure 2. For the low-intensity cropping system designed to conserve the environment, the use of synthetically derived pesticides and fertilizers is not leaved out at all, but the selection of products that are applied is carried out in a cautious form to avoid as much as possible negative side effects on human beings, natural species and environmental elements. The farming system that is found in the lower-right quadrant of Figure 2 accomplishes these characteristics and for that reason is named as **eco-friendly agriculture**.

Figure 2. Classification of agricultural systems



3.1.2. Pesticide Use

A meaningful assessment of pesticides use in agricultural production should not only cover the quantities applied, but also evaluate characteristics of the applied products and the techniques and technology of application. In this analysis, two particular aspects of pesticide use are taken into consideration, intensity and innovation.

The complementarities of the pesticide use intensity and innovation may be explained with the statement that a reduction in quantity of applied pesticides might simultaneously imply an increase on environmental damage, if more harmful pesticides are applied, or at contrary, increase in the amount of chemical products used in crop protection could be followed by a decrease of negative direct and side effects, in the case that more environmentally friendly pesticides are employed (OECD, 1999).

In this analysis, the assessment of pesticide use is based on active substances (AS) applications instead of pesticide products quantities, as the degree of toxicity, persistence and mobility of these products depends on the concentration of AS (Idem). In addition, one particular pesticide product may contain more than one AS. Furthermore, from a single AS, several pesticide products might be manufactured and records containing the use of single products in every EU country do not exist. (Normally, statistics on pesticide use refer to the application of AS).

3.1.2.1. Pesticide Use Intensity

Pesticide use intensity is defined by the quantity of AS that is applied in crop production. When comparing the pesticide use for one crop in different countries or regions, the applied amount might vary noticeably, because the quantities depend on environmental endowments (e.g. soil properties), natural conditions (e.g. weather), relative pressure on land resources, income levels and policy priorities. Therefore, comparisons of absolute values of pesticide use should be interpreted with caution and preferably avoided. Thus, when evaluating pesticide use, it is helpful to have a common unit of measure, for example per hectare, to facilitate analysis and evaluations (OECD, 1999).

Pesticide use intensity can be assessed through establishing average doses of AS per unit of area under production and for example expressed in terms of kilograms of AS per hectare (kg AS/ha). In the case that the occurrence of pests, diseases or weeds could be exactly estimated; then, the recommended dosages of AS that should be applied to effectively control them might be calculated and subsequently, an index of use or number of required applications can be obtained. Such methodology has been approximated, as the recommended dosage has been assumed according to empirical information and data, and employed to evaluate programmes on pesticide use reduction in Denmark with the Treatment Frequency Index (Orum, 2003) and in Germany with the Standardised Treatment Index (see Rossberg et al., 2002).

In this analysis, ***pesticide use intensity*** is calculated as the amount of AS applied in one hectare of crop production during one cropping season and is expressed in terms of ***kg AS/ha***.

3.1.2.2. Pesticide Use Innovation

In pesticide use innovation there are two technical options for farmers in the short and medium-term. The first is the more efficient use of pesticides products and the second is the use of safer products (see Mac Rae, 1990). The more efficient use of pesticide products may be related to the utilisation of more precise techniques and technologies of application. And it also may follow a more accurate establishment of the quantities of pesticide products that should be applied to avoid crop losses, for instance by implementing crop production practices such as use of economic thresholds.

The term safe is not included within the definitions of the International Code of Conduct on the Distribution and Use of Pesticides adopted by the Food and Agriculture Organization of the United Nations (FAO) in 2002. In this code, the inherent property of an AS having the potential to cause undesirable consequences such as adverse effects or damage to health or the environment is known as “Hazard”.

Due to the fact that in the statistical databases information concerning types and quantities of pesticides applied in agricultural production are often available, while the classification and utilisation of different equipments in the application of pesticides is seldom documented in this analysis, the assessment of pesticide use innovation is based on evaluation of the properties of AS applied in crop production, instead of comparison of techniques and technology of application.

For the evaluation of the AS properties, there are three aspects that might be considered. The first is the functioning of the legislation on authorisation of and regulation on use of AS. The second feature is the existence of standards, recommendations or restrictions on the use of AS that should be followed to obtain a certification of good agricultural practices in IP or OF production. The third element is the standard evaluations of the toxicity for human and natural species and the persistence or mobility in the environment.

When an AS is authorized to be used in the EU, then it should be included in the Annex I of the Directive 91/414/EEC, which concerns the placing of plant protection products on the market. The requirements that an AS should fulfil to be included in the Annex I are that the residues (when applied under good agricultural practice principles) do not have any direct or indirect harmful effect on human and animal health or on groundwater and any unacceptable influence on the environment and impacts on non-target species (see article 5).

Certifications of good agricultural practices like IP and OF differ from legislative aspects such as the registration of AS, because the fulfilment of these standards and the observance of recommendations is voluntary. The benefits of having a certified production are related to access into specialised markets (e.g. organic market), in which, normally, the prices of crop outputs are more favourable than those prices paid for regular products (i.e. no certified). The setting of certification standards and issuing of guidelines for a specific production may be set by organisations that represent the private sector, for example Globalgap, the scientific community, for instances the International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) or governmental organisations, such as the European and Mediterranean Plant Protection Organisations (EPPO) or the EC.

The assessment of pesticide use innovation might be restricted if the criteria of evaluation are only the regulatory status and the completion of certification standards. The weakness of the regulatory status as an indicator may be demonstrated with the fact that from a list of 1054 AS that is linked in the website of the EC (last updated 23.01.2008)[1] only 164 AS are until now included with a fully completed process of authorisation in the Annex I of the Directive 91/414/EEC. For 327 AS the authorisation process is still under evaluation and the remaining 563 AS have been banned, never notified or excluded from the Annex I.

Regarding statistics and percentages of the crop production, which counts with the certification of IP or good agricultural practices, the information is hardly available. In the case of OF, the information published by Eurostat only covers a few countries of the EU. The German center for information of markets and prices of agricultural and forestry commodities and food (ZMP) provides an online database, in which the areas under OF for different groups of crops in the EU countries are included. But, the inclusion of the percentages of production under OF in a pesticide use innovation indicator should be taken with reserve. Although, the implementation of OF is a signal for the adoption of levels of alternative farm

[1] http://ec.europa.eu/food/plant/protection/evaluation/index_en.htm

management practices, the AS that are applied may present higher environmental risks than those generated from the use of synthetically derived pesticides. For instance, the excessive use of Inorganic Sulphur affects the predatory phytoseiid mites and for this reason its application in IP of pome-fruits in Europe should be limited (IOBC, 2002).

As the utility of the two above described criteria (regulatory status and fulfilment of recommendations contained in guidelines for IP and OF) is limited, the inclusion of evaluations about how target oriented and toxic the AS are, and also of indicators about their persistence and mobility on the environment, contributes to enhance the precision in the assessment of an indicator of pesticide use innovation. However, it is important to remark, that these evaluations and indicators of AS characteristics represent only potential effects on the environment, to humans and animals and they (the evaluations and indicators) are, in most of the cases, calculated under standard conditions.

The side effects on beneficial organisms is an indicator of how target oriented an AS is. For the evaluation of the toxicity of AS, the hazardousness for human health and the negative effects on natural species, as for example bees and fishes, can be employed. Evaluations of the persistence and mobility of AS include quantifications of their rates of degradation in the soil and their capacity to dissolve in water, among others.

In this analysis, the evaluation of ***pesticide use innovation*** is based on the status of the authorisation process and recommendations of use under IP (only for case study apple) and in addition, the side effects on beneficial organisms, hazardousness for human health, toxicity for natural species and the potential risk for groundwater are taken into account. The selection of these variables is explained in the Chapter 3.2.2.

3.2. Variables and Database to assess Pesticide Use

3.2.1. Pesticide Use Intensity

3.2.1.1. Data and Sources

The quantity of AS (in tons) applied between 2000 and 2003 in the production of cereals and fruit trees in different EU countries: This information was published by Eurostat in 2007 and is presented in the Table 1 for cereals and in the Table 2 for fruit trees.

Areas cultivated (in 1000 ha) between 2000 and 2003 in the production of cereals and fruit trees in different EU countries: This information was published by Eurostat in 2007 and is presented in the Table 1 for cereals and in the Table 2 for fruit trees.

AS Dosage (in kg AS/ha) used between 2000 and 2003 in the production of cereals and fruit trees in different EU countries: This information was published by Eurostat in 2007 and is presented in the Table 1 for cereals and in the Table 2 for fruit trees.

Areas cultivated (in 1000 ha) between 2000 and 2003 with wheat and apple in different EU countries: This information is available in the website of the FAO, was consulted in November 2007 and is presented in the Table 1 for wheat and in the Table 2 for apple.

3.2.1.2. Data Limitations – Quality of the Information

It is reasonable to make two commentaries about the information published by Eurostat that is utilised in the assessment of intensity in pesticide use to support the convenience of employing this information (as the database is trustful and comparable) to achieve our objective of contrasting different patterns in crop protection across Europe.

First, the information has been prepared by the European Crop Protection Association (ECPA), whose members besides national crop protection associations are pesticide manufacturing companies, which cover about 90% of the European market (ECPA estimation). They have collected and provided data on use of AS and for the remaining percentage of the market, they made estimations based on sales of products and compared with other sources of information to evaluate the accuracy of the data.

Second, for each country of the EU, the figures included in the publication are grouped by crop types (e.g. arable or speciality crops) and crop groups (e.g. cereals, oilseeds, citrus, fruit trees, vegetables, etc.) and are available for at least four years (between year 2000 and 2003). Attempts to allocate the use of AS in production of one specific crop will produce uncertainty, because one AS could be used in production of several crops. For that reason in this study, we compare the use of AS in the cropping groups cereals (for the case study crop wheat) and fruit trees (for the case study apple).

Dissimilarly, there are three disadvantages of using this information in the assessment of pesticide use intensity. One weakness is the possibility that the percentage of the production of the case study crop is very low within a crop group. Other disadvantage is that the dose calculated and presented in the publication corresponds to a theoretical dosage, it means that the dosage is equal to the quotient between the quantity of AS used and the area under production, which might be different than actually applied doses, as AS are not always applied in the whole area under production. The last problem when using this information is that other products different than insecticide (I), fungicide (F), herbicide (H) and plant growth regulators (PGR) are also included in the publication (for those other products, evaluations or classifications according with the variables employed to assess pesticide use innovation are limited, therefore they will be neither taken into account for the estimation of pesticide use intensity).

In chapter 3*.2.1.3, Data Coverage,* commentaries about the relative production of case study crops within a crop group are presented. Similarly, in the section 3*.2.1.4, Data Correction,* the treatment given to the information to improve the quality of the analysis is described. The uncertainty generated associated with the theoretical dosage will be removed, when a more detailed survey on the farm level will be conducted (i.e. second phase of the project).

Table 1. Area under production of cereals and wheat in 1000 ha, quantity of AS used in cereal production in tons and dose in kg AS / ha in cereal production in different countries of the EU between 2000 and 2003

	2000				2001				2002				2003			
	AS	Area	Dose	Wheat	AS	Area	Dose	Wheat	AS	Area	Dose	Wheat	AS	Area	Dose	Wheat
	ton	1000 ha	kg AS / ha	1000 ha	ton	1000 ha	kg AS / ha	1000 ha	ton	1000 ha	kg AS / ha	1000 ha	ton	1000 ha	kg AS / ha	1000 ha
Austria – AT	607	666	0.9	293.8	635	653	1	287.8	485	642	0.8	288.8	362	636	0.6	272
Belgium - BE*	1061	306	3.5	224.1	850	274	3.1	190.9	822	292	2.8	214.4	808	284	2.8	202.4
Czech Rep. – CZ	1667	1603	1	970.4	1896	1562	1.2	923.2	1074	1492	0.7	848.8	1324	1374	1	648.4
Germany – DE	15795	6655	2.4	2968.9	15710	6649	2.4	2897.2	15336	6542	2.3	3014.6	12366	6376	1.9	2963.7
Denmark – DK	1376	1500	0.9	627.5	1524	1538	1	634.1	1462	1528	1	576.6	1703	1485	1.1	664.3
Estonia – EE	29	329	0.1	69.0	55	274	0.2	59.7	63	259	0.2	65.4	63	263	0.2	67.2
Spain - ES	2494	6374	0.4	2353.0	2652	5915	0.4	2177.0	3083	6264	0.5	2406.6	3502	6151	0.6	2151.5
Finland – FI	582	1167	0.5	149.5	675	1156	0.6	144.6	846	1190	0.7	174.5	699	1192	0.6	191.3
France – FR	21309	7310	2.9	5248.4	19649	7020	2.8	4766.6	19825	7497	2.6	5230.0	15557	7267	2.1	4876.1
Greece – GR	278	1005	0.3	857.8	231	1162	0.2	875.3	211	1077	0.2	870.0	250	1035	0.2	847.9
Hungary – HU	757	1571	0.5	1024.4	1076	1823	0.6	1205.6	1132	1748	0.6	1110.5	922	1741	0.5	1113.8
Ireland – IE	997	279	3.6	78.0	1017	286	3.6	84.9	1027	299	3.4	102.7	810	303	2.7	95.7
Italy – IT	1724	3070	0.6	2322.8	1651	3024	0.5	2289.4	1696	3172	0.5	2415.5	1486	2984	0.5	2266.8
Lithuania – LT	82	980	0.1	370.4	143	936	0.2	352.2	233	915	0.3	335.1	253	862	0.3	336.5
Latvia – LV	42	420	0.1	158.1	74	444	0.2	166.8	114	415	0.3	153.5	107	429	0.3	167.8
Netherlands - NL	1031	206	5	136.7	939	209	4.5	124.7	1077	209	5.1	135.2	1257	201	6.3	129.3
Poland – PL	4965	8661	0.6	2635.1	6321	8596	0.7	2627.1	5904	7975	0.7	2414.2	6091	7807	0.8	2308.1
Portugal - PT	312	425	0.7	226.3	284	338	0.8	183.5	234	375	0.6	230.7	228	309	0.7	174.3
Sweden - SE	1043	1208	0.9	401.6	1067	1165	0.9	399.2	1132	1116	1	339.6	1539	1146	1.3	411.4
Slovenia - SI	42	55	0.8	38.3	48	57	0.8	39.3	49	54	0.9	35.7	37	55	0.7	35.6
Slovakia - SK	388	673	0.6	405.3	505	714	0.7	445.3	476	682	0.7	405.8	369	650	0.6	306.9
United Kingdom - UK	10692	3348	3.2	2086.0	10483	3014	3.5	1635.0	11797	3245	3.6	1996.0	10009	3059	3.3	1837.0

Sources: Eurostat, 2007 and FAO, 2007

* Data for Belgium and Luxemburg

Table 2. Area under production of fruit tress and apple in 1000 ha, quantity of AS used in fruit trees production in tons and dose in kg AS / ha in fruit trees production in different countries of the EU between 2000 and 2003

	2000				2001				2002				2003			
	AS	Area	Dose	Apple	AS	Area	Dose	Apple	AS	Area	Dose	Apple	AS	Area	Dose	Apple
	ton	1000 ha	kg AS / ha	1000 ha	ton	1000 ha	kg AS / ha	1000 ha	ton	1000 ha	kg AS / ha	1000 ha	Ton	1000 ha	kg AS / ha	1000 ha
Austria – AT	87	8	11.3	5.98	48	8	6.2	6.06	89	7	12.2	5.86	95	7	12.9	5.87
Belgium - BE*	353	18	19.3	9.96	180	18	9.8	9.86	485	18	26.2	9.66	484	18	26.3	9.43
Germany - DE	705	55	12.8	73.04	965	55	17.4	70.00	906	48	18.8	70.00	982	48	20.5	31.16
Denmark - DK	49	5	10.7	1.68	71	5	15.3	1.78	55	5	12	1.57	50	5	10.7	1.62
Spain - ES	3105	961	3.2	49.10	3249	968	3.4	48.76	2730	852	3.2	43.21	2490	971	2.6	46.02
Finland – FI	20	1	38.6	0.51	19	1	35	0.53	23	1	39.5	0.56	14	1	22.4	0.60
France – FR	2559	196	13.1	69.70	3142	189	16.6	66.00	3201	167	19.2	65.60	2747	167	16.5	59.82
Greece - GR	1323	137	9.6	14.10	1237	135	9.2	15.50	1311	136	9.6	13.70	1233	133	9.3	13.60
Hungary - HU	419	95	4.4	34.50	510	87	5.8	57.20	543	79	6.9	35.82	441	93	4.8	43.49
Ireland – IE	2	2	1.5	0.80	11	2	7.4	0.70	12	2	8.3	0.60	1	2	1	0.60
Italy – IT	6297	461	13.7	62.53	6273	464	13.5	62.65	6962	462	15.1	60.53	5905	454	13	56.93
Lithuania - LT	3	36	0.1	31.00	2	37	0.1	31.30	3	38	0.1	24.80	4	15	0.2	19.26
Latvia – LV	3	9	0.4	8.13	4	12	0.3	8.16	3	11	0.3	8.22	4	13	0.3	8.25
Netherlands - NL	253	20	12.8	12.84	181	19	9.6	11.72	367	19	19.8	11.18	371	18	21	10.30
Poland – PL	545	277	2	165.10	590	280	2.1	166.41	652	272	2.4	168.46	770	258	3	159.28
Portugal - PT	627	130	4.8	21.21	542	130	4.2	21.33	516	130	4	21.39	527	130	4.1	21.58
Sweden - SE	43	2	22.6	1.42	62	2	32.9	1.42	30	2	16.3	1.33	27	2	14.3	1.33
Slovenia - SI	12	5	2.6	3.08	17	5	3.7	3.08	35	4	7.9	3.29	24	4	5.5	3.10
Slovakia - SK	30	5	5.9	3.05	48	7	7.2	4.13	44	6	7.4	4.67	32	6	5.7	3.52
United Kingdom - UK	46	22	2.1	12.80	87	22	3.9	13.00	72	20	3.6	11.19	58	20	2.9	9.85

Sources: Eurostat, 2007 and FAO, 2007

* Data for Belgium and Luxemburg

3.2.1.3. Data Coverage

- **Countries**

Four countries are not included in the calculation of the pesticide use intensity indicator for cereal production. Bulgaria, Romania, and Cyprus, because the publication does not contain statistics on the use of AS in these countries, Malta due to the limited information that is published (i.e. just the theoretical dosage). In addition, the data for Luxembourg have been added to Belgium values.

The crop group cereals include the production of barley, triticale, wheat, oats, rye, millet and paddy rice. In 2003, the average area under wheat production in the EU accounted for 49 % of the crop group and the countries with the lowest wheat area relative to production of cereals were Finland (16%), Estonia (26%) and Poland (30%). The highest percentages of wheat production were registered in Greece (71%), Italy (76%) and Belgium (82%). Other percentages are shown in the Table 3.

Table 3. Area under production of wheat relative to the crop group cereals in 2003 (in %)

	AT	BE	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LV	NL	PL	PT	SE	SI	SK	UK
%	43	71	47	46	45	26	35	16	67	82	64	32	76	39	39	64	30	56	36	65	47	60

Data sources: Eurostat, FAO

The intensity of pesticide use in the production of fruit trees is estimated for 20 EU countries, in addition to countries excluded when evaluating intensity in cereals production, other two countries were not taken into account, Czech Republic as the information about area under production is not reliable and Estonia because the quantity of AS was rounded down to zero.

The crop group fruit trees include growing of pome fruit (i.e. apple and pear), stone fruit (i.e. apricot, cherry, nectarine, peach and plum), orchards (e.g. dates, figs) and other fruits (e.g. strawberry, gooseberry, raspberry). In 2003, the area under apple growing represented 51% of the production of fruit trees. The countries with the least percentage of apple area within the fruit trees production were Spain (5%), Greece (10%), Italy (14%) and Portugal (17%), while Finland (97%), Lithuania (83%) and Austria (79%) presented the highest percentages of apple area for the crop group. Other percentages of areas under production of apples are listed in the Table 4.

Table 4. Area under production of apples relative to the crop group fruit trees in 2003 (in %)

	AT	BE	DE	DK	ES	FI	FR	GR	HU	IE	IT	LT	LV	NL	PL	PT	SE	SI	SK	UK
%	79	51	65	36	5	97	36	10	47	60	14	83	63	58	62	17	67	70	62	46

Data sources: Eurostat, FAO

3.2.1.4. Data Correction and Weighting

Two treatments are carried out to improve the accuracy (i.e. reduce uncertainty) of the pesticide use intensity estimations. One at country level by excluding those pesticides, that do not belong to the groups I, F, H or PGR. This selection was possible with the information of a detailed list, which contains the AS names and quantities used in the production of cereals and fruit trees in different EU countries in 2003, that list was provided by the Unit for Environmental Statistics of Eurostat.

In cereal production the AS, that were removed, were Choline Chloride (from data for BE, DK, FI, FR, HU, IE, IT, SE, UK), Petroleum Oils (in statistics of ES, NL, IT) and Molluscicide (for FR, IT values). In the production of fruit trees, the subtractions corresponded to 1,3-

Dichloropropene (in BE, ES), Petroleum Oils (in ES, FR, GR, IT, PT, SI) and Molluscicide (in ES, GR, IT, PL). It is important to mention that Choline Chloride is used to control rats, Petroleum Oils is an additive (used to lighten formulations), Molluscicide is utilised to control roundworms and 1,3-Dichloropropene is employed in soil treatments. The exclusion of these AS does not signify that their use does not generate effects on the environment, but the aim is to have an evaluation for AS types for which the statistics of use are comprehensive and evaluations of effects on human health and the environment, as well as characteristics of persistence and mobility are available in the literature.

For the year 2003, the quantity of AS that should be removed is exactly known for both crop groups, for the other three years under consideration (i.e. 2000/02) was assumed a proportional reduction, except in production of fruit trees, for which the quantities of 1,3-Dichloropropene used in BE and Petroleum Oils used in ES, IT and PT were significant and available in the publication of Eurostat.

The average dose of AS used in production of cereals and fruit trees for all European countries was calculated by weighting the mean with the area under production. The meaning of this weighted average is that the larger the area, in which the dose is used (at national level), the more that this dosage influence the European average. In other words, that a national dosage carries more importance in the EU mean, if the area harvested is larger than in other countries. The procedure to obtain the weighted average is to divide the sum up of the product of each national dose and the area harvested in each country by the total area under production of the crop group in the EU.

3.2.1.5. Pesticide Use Intensity Indicator (quantity of AS applied)

The average doses used in the production of the crop group cereal and fruit tree between 2000 and 2003 in different EU countries and expressed in kg AS/ha are presented in the Table 5. The EU weighted averages (according with the area under production in each EU country) of doses used between 2000 and 2003 in production of cereals is equal to 1,37 kg AS/ha and for production of fruit trees is equal to 5.97 kg AS/ha.

Table 5. Dose used in production of cereals and fruit trees between 2000 and 2003 in the EU

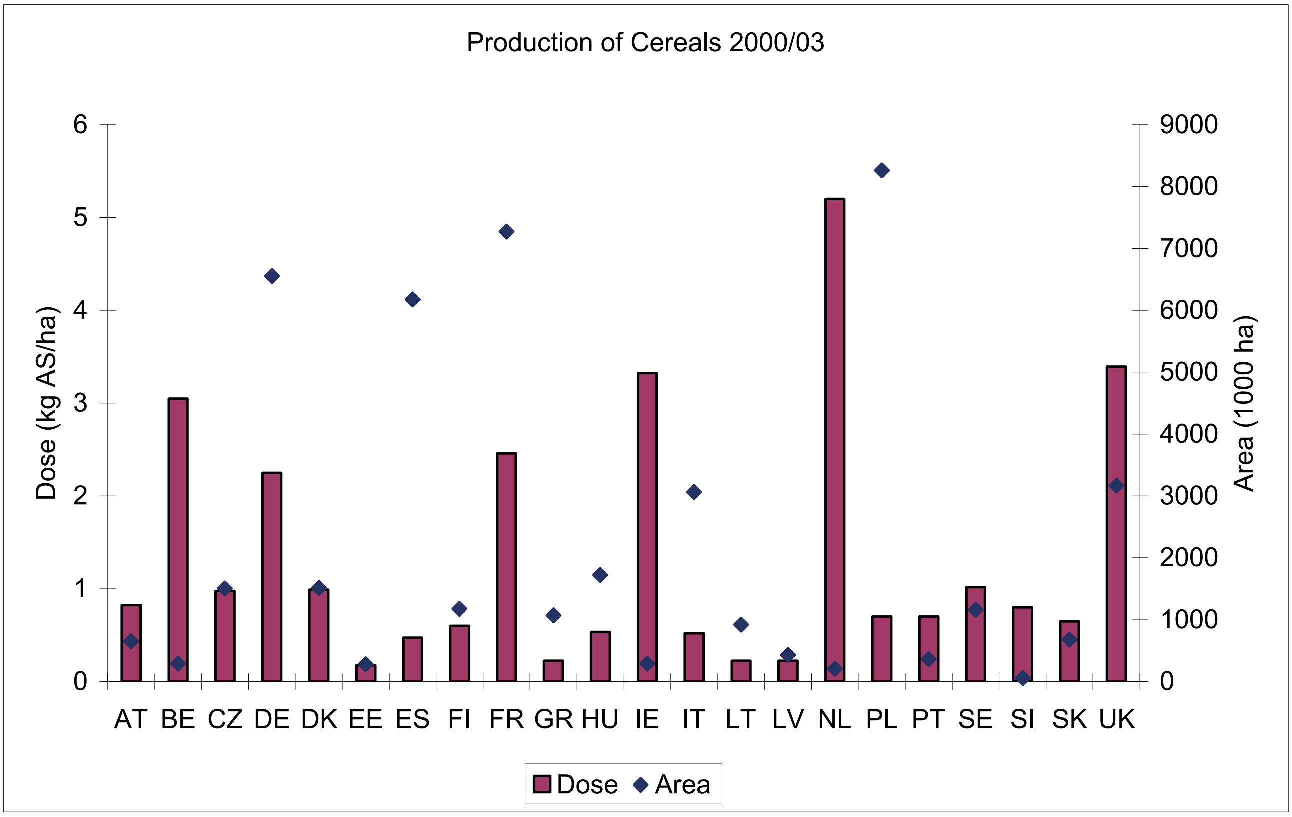
CEREALS	**2000/03 Dose kg AS/ha**	**CEREALS**	**2000/03 Dose kg AS/ha**	**FRUIT TREES**	**2000/03 Dose kg AS/ha**	**FRUIT TREES**	**2000/03 Dose kg AS/ha**
AT	0.825	**IE**	3.325	**AT**	10.65	**IT**	8.994
BE	3.048	**IT**	0.521	**BE**	11.456	**LT**	0.125
CZ	0.975	**LT**	0.225	**DE**	17.375	**LV**	0.325
DE	2.25	**LV**	0.225	**DK**	12.175	**NL**	15.8
DK	0.99	**NL**	5.2	**ES**	3.088	**PL**	2.371
EE	0.175	**PL**	0.7	**FI**	33.875	**PT**	3.544
ES	0.474	**PT**	0.7	**FR**	14.4	**SE**	21.525
FI	0.598	**SE**	1.018	**GR**	9.360	**SI**	4.917
FR	2.459	**SI**	0.8	**HU**	5.475	**SK**	6.55
GR	0.225	**SK**	0.65	**IE**	4.55	**UK**	3.125
HU	0.535	**UK**	3.392				
Weighted average: 1.37 kg AS /ha				**Weighted average: 5.97 kg AS /ha**			

Data source: Eurostat, 2007 (own calculation)

In the Figure 3 is illustrated that in the estimation of the European indicator of pesticide use intensity between 2000 and 2003 PL, FR, DE and ES are the countries that have more influence in the weighted average, which represent the breaking point between low and high intensity levels and also that in NL, UK, IE and BE, the more intensive use of pesticides

occurs. From the last four mentioned countries, only in the UK the area under crop production is significant, it means, strongly influences the weighted average.

Figure 3. Average AS use (dose) and area in cereal production in the EU in 2000/03



Data source: Eurostat, 2007

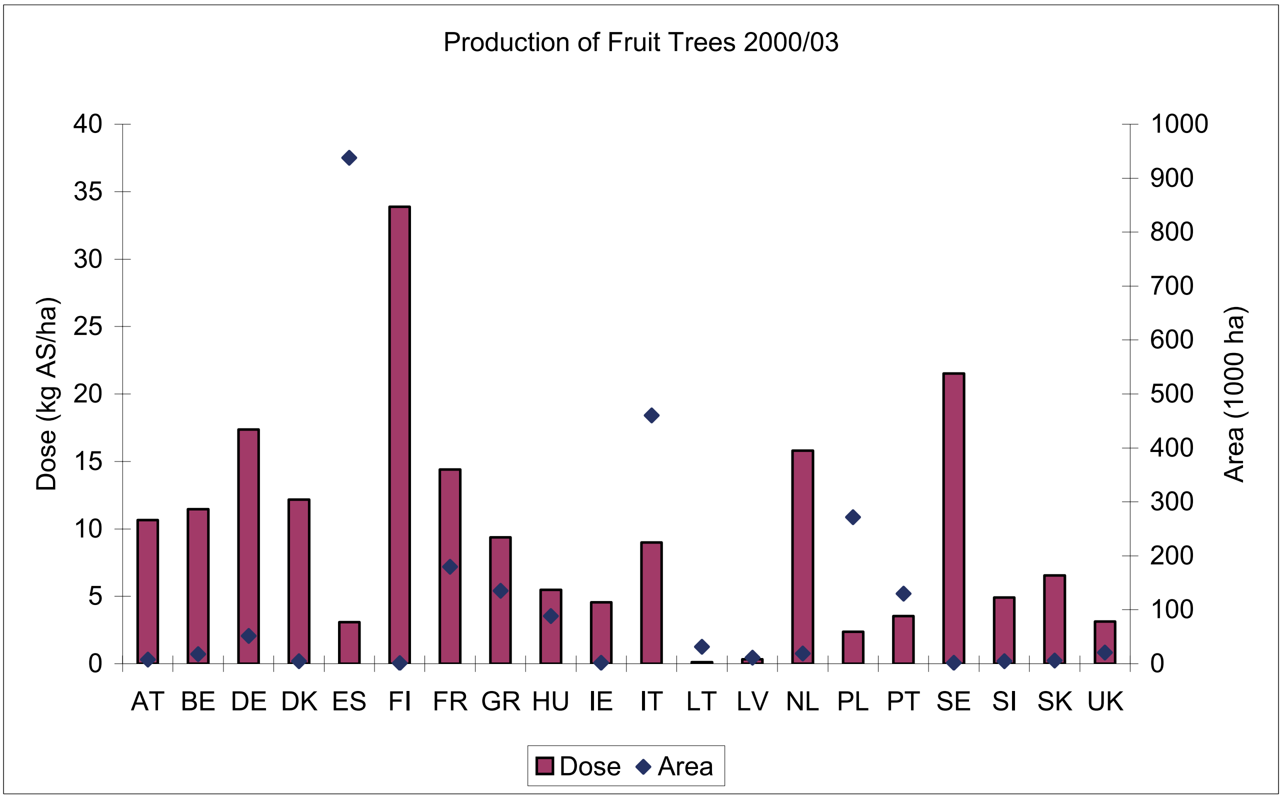


Figure 4. Average AS use (dose) and area in production of fruit trees in the EU in 2000/03

Data source: Eurostat, 2007

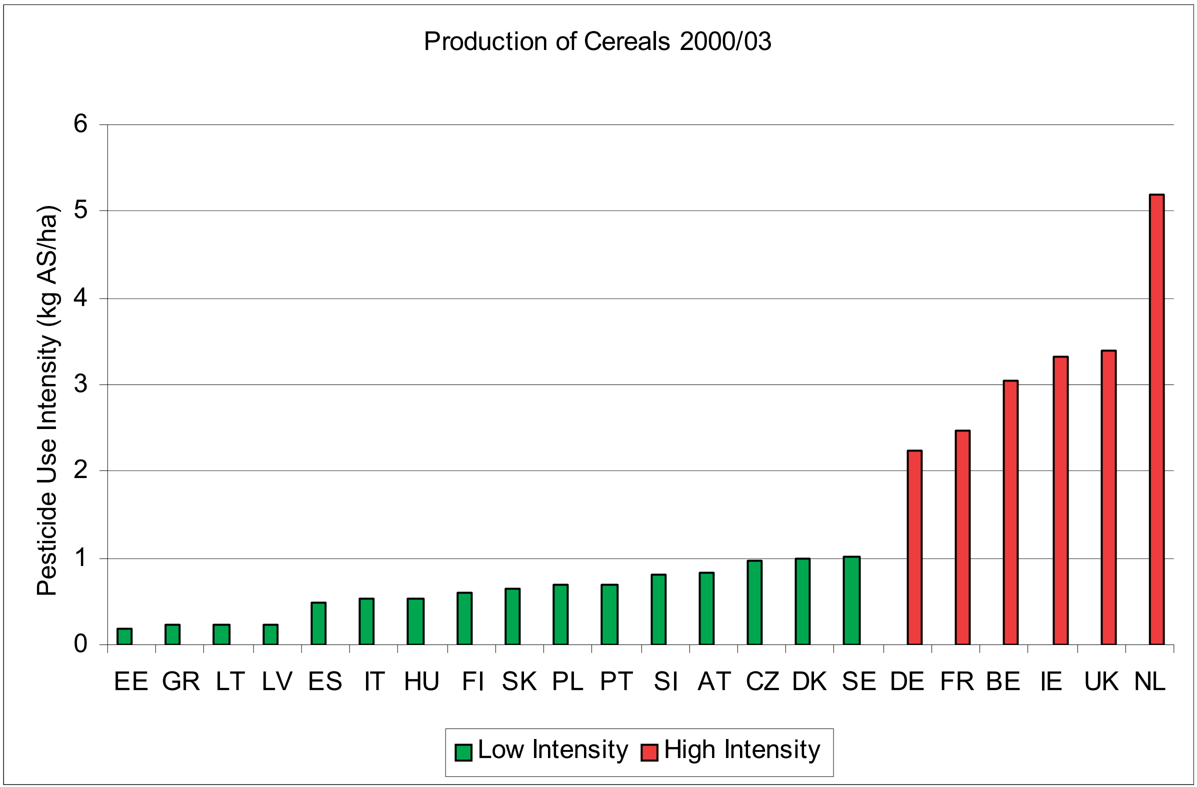
The pesticide use intensity in fruit tree production in the EU between 2000 and 2003 is strongly influenced by ES, IT, PL and FR as depicted in the Figure 4. The most intensive production in respect to pesticide use take place in FI, SE, DE, NL and FR, from which only France exerts a significant influence in the weighted average.

The classification of pesticide use in high and low intensity levels between 2000 and 2003 in different EU countries is shown in the Figure 5 for cereal production and in the Figure 6 for fruit tree production. In Figures 5 and 6, pesticide use intensity doses are marked in red for high levels and in green for low levels. It is observable that in production of fruit trees, the pesticide use intensity is better distributed with a homogeneous increasing tendency (excluding the extreme values FI, the highest one and LT and LV, the lowest ones) than in production of cereals, where groups with similar values are perceptible and the breaking point between high and low levels is easily detected.

Between 2000 and 2003, in the production of cereals the EU countries with the highest pesticide use intensity are NL (5.2 kg AS/ha), UK (3.39 kg AS/ha), IE (3.33 kg AS/ha), BE (3.05 kg AS/ha), FR (2.46 kg AS/ha) and DE (2.25 kg AS/ha), while the opposite tendency is found in EE (0.175 kg AS/ha), GR (0.225 kg AS/ha), LT (0.225 kg AS/ha) and LV (0.225 kg AS/ha). In the production of fruit trees the highest values of pesticide use intensity correspond to FI (33.9 kg AS/ha) with an exceptionally elevated theoretical dose, SE (21.6 kg AS/ha), DE (17.4 kg AS/ha), NL (15.8 kg AS/ha) and FR (14.4 kg AS/ha), while the lowest values are generate in LT (0.125 kg AS/ha) and LV (0.325 kg AS/ha).

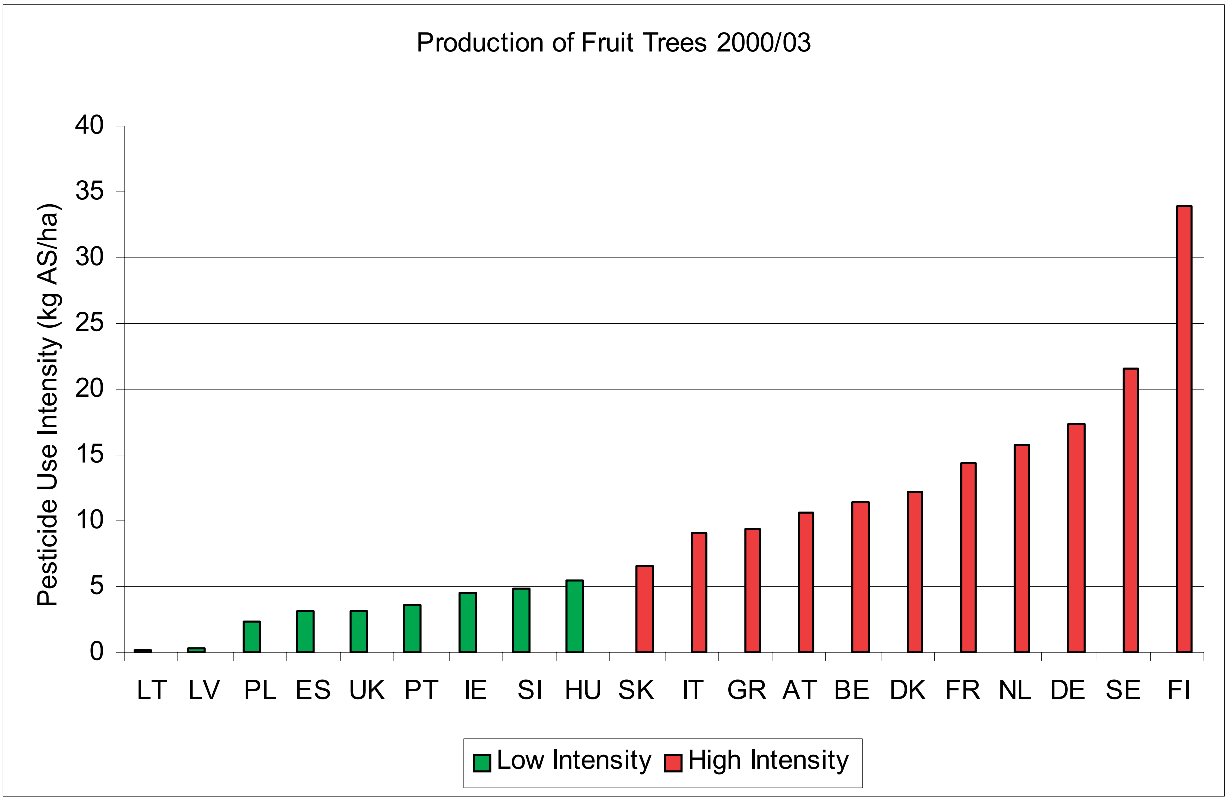
The calculation of an average value of four years (i.e. between 2000 and 2003) to assess pesticide use intensity makes possible to include changes in weather and natural conditions

Figure 5. Pesticide use intensity in production of cereals in the EU between 2000 and 2003



Data source: Eurostat, 2007 (own calculations)

Figure 6. Pesticide use intensity in production of fruit trees in the EU between 2000 and 2003



Data source: Eurostat, 2007

3.2.2. Pesticide Use Innovation

3.2.2.1. Data and Sources

Initially, seven variables were selected to assess the properties of those AS used in production of cereals and fruit trees:

1) Regulatory status
2) Hazardousness to human health
3) Side effects in beneficial organisms
4) Toxicity to natural species
5) Potential risk for groundwater
6) Persistence in water bodies and
7) Recommendations to avoid or restrict the use according with IP principles (only for fruit trees).

Then an survey (EOS) was conducted among experts, who are involve in ENDURE with the purpose of assess the suitability of the seven variables chosen and to estimate weighting factors to aggregate the variables to an indicator for pesticide use innovation.

The results of the EOS might be summarized with two conclusions. First, it is prudent to evaluate separately inherent properties (i.e. hazardousness) of the AS and regulatory aspects (i.e. authorisation status). Second, in the evaluation of the properties of AS, it is

questionable to include the solubility in water and it would be better to incorporate indicators of persistence in the soil.

For the evaluation of the characteristics and properties of AS applied in the production of cereals and fruit trees during the year 2003 the quantity (in tons) and type (name and category) of the most utilised active ingredients are taken as a date base. The information published by Eurostat in 2007 was complemented with a detailed list, which was provided by the Unit for Environmental Statistics of Eurostat. In the Annex 1, the AS used in the production of cereals in 2003 are summarized in the Table 1. Table 2 consists of similar information for the production of fruit trees. Next, six variables (solubility in water is excluded according with the results of the EOS) that are used in the evaluation of AS, are described.

Variable 1: Regulatory status

The status of the process of authorisation to use AS in the EU is divided in three categories, AS included (in), AS not included (out) in the Annex I of the Directive 91/414/EEC and AS for which the process is still being under evaluation (pending). In addition to this classification the AS are grouped in ingredients existing on the market before and after 1993 (old and new ones). This information is available on the website of the EC, was consulted in December 2007. It is presented in the Annex 1 Table 5 and Table 6 for the production of cereals and fruit trees under the columns named as EC (for time of placement on the market) and Dir (for status).

Variable 2: Recommendations of use under IP

IOBC have prepared and published in 2002 a set of guidelines for IP of pomefruits in Europe. In the guidelines, some criteria that should be observed when selecting a pesticide are mentioned and in addition there is a list of pesticide groups, for which the use is restricted or not permitted. The criteria examined to decide the inclusion of an AS in the list of restricted pesticides include toxicity to man, key natural enemies and other natural organisms, pollution of ground and surface water, ability to stimulate pests, selectivity, persistence, incomplete information and necessity of use.

The chemical classes that are not permitted in IP production of pome fruits include: pyrethroid and organochlorine I and A, non-naturally occurring PGR and toxic, water polluting or very persistent H. Similarly, the use of benzimidazole and dithiocarbamate F, sulphur and Residual H (i.e. AS: chlosulfuron, triasulfuron, metsulfuron-methyl, sulfosulfuron, iodosulfuron-methyl, mesosulfuron-methyl, flumetsulam, metosulam, imazethapyr, imazapyr, imazapic, atrazine, simazine, diuron, metribuzin, pendimethalin, trifluralin, isoxaflutole, metolachlor) is restricted, so that beneficial organisms are not affected. In the column called IP in the Table 6 of the Annex 1, the AS, whose use under IP should be restricted or avoided are referenced.

Variable 3: Hazardousness for human health

The risk for human health generated from use of AS is categorised in five classes of hazardousness: extremely (class Ia), highly (class Ib), moderately (class II), slightly (class III) and unlikely (class U) to present acute hazard. This information was taken from a publication of WHO. In the Tables 5 and 6 of the Annex 1 under the columns called as WHO the corresponding classifications are presented for AS used in the production of cereals and fruit trees respectively.

Variable 4: Side effects on beneficial organisms

For the evaluation of side effects on beneficial organisms derived from use of AS, three insects, predatory mites (Typhlodromus pyri), parasitoids (Trichogramma cacoeciae) and

lacewings (Chrysoperla carnea) were randomly selected from a list of 14 organisms. These side effects might be qualified as harmless or slightly harmful (class N), moderately harmful (class M) and harmful (class T). The information about the selectivity of pesticides has been elaborated by IOBC (for a specific concentration of AS) and is available in their website, which was consulted in December 2007. The evaluation of side effects on beneficial organisms for the AS used in production of cereals and fruit trees is presented in the Tables 5 and 6 of the Annex 1 respectively, under the columns B1 for effects on predatory mites, B2 for parasitoids and B3 for lacewings.

Variable 5: Toxicity to natural species

Similarly to the evaluation of side effects on beneficial organisms generated from use of AS (with a specific concentration), tests of toxicity to bees, earthworms and fishes have been conducted by IOBC. Those evaluations refer only to absence (class -) or presence (class +) of toxicity, but do not disclose any degree of toxicity. The columns N1 (for bees) and N2 (for fishes) of the Tables 5 and 6 in the Annex1 compile the evaluations of toxicity corresponding to those AS used in production of cereals and fruit trees respectively. This information is available in the website of IOBC and was consulted in December 2007.

Complementarily, estimations of the toxicity to zooplankton and fishes derived from use of AS were included. Those evaluations are divided in five levels: not acutely (class N), slightly (class S), moderately (class M), highly (class H) and very highly (class V) toxicity. The Tables 5 and 6 of the Annex 1 contain toxicity to fishes (column N3) and zooplankton (column N4) that might be generated from those AS used in production of cereals and fruit trees respectively. These evaluations of the toxicity to natural species have been made available in an online pesticide database published by the Pesticide Action Network (PAN). This database was consulted in December 2007.

Variable 6: Potential risk for groundwater

The potential of an AS to move toward groundwater is indicated by the Pesticide Movement Rating. This indicator is derived from an empirical value called Groundwater Ubiquity Score, which relates the persistence of AS in soil and the tendency of AS to bind to soil particles. The persistence in the soil is measured through a soil half life value that indicates the number of days in which AS degrades to half of an initial concentration in a typical soil. The tendency of AS to bind to soil particles is asserted through a sorption coefficient which is calculated in the laboratory. The potential to move toward groundwater is divided in six categories: extremely low (class E), very low (class VL), low (class L), moderate (M), high (class H) and very high (class VH). The columns designated as PMR in the Tables 5 and 6 of the Annex 1 include the potential risk for groundwater for those AS applied in the production of cereals and fruit trees. This information was taken from an online pesticide properties database, which has been prepared by the National Pesticide Information Center of the United States (NPIC). The website of NPCI was consulted in December 2007.

3.2.2.2. Data Limitations – Quality of the Information

In the assessment of an indicator for pesticide use innovation and comparison among different countries of the EU, the information published by Eurostat containing the top-five AS that were applied in 2003 in the production of the crop groups cereals and fruit trees is used. Similarly, as mentioned in the section 3.1.1.2 (Data Limitations – Quality of the information when calculating an indicator for pesticide use intensity), the information about AS applied was prepared by ECPA, which covers about 90% of the pesticide market and complemented with estimations for the remaining part of the market.

There are two aspects that affect the quality of this top-five applied AS information. First and due to commercial reasons, some ciphers related to specific AS considered as a key within the pesticide marked are confidential. Second, within the top-five AS list for some countries, it is possible to find ingredients different than I, F, H or PGR. Once again, as mentioned in the section 3.1.1.2, in this analysis will be only included AS belonging to these four major groups of pesticides, to avoid gaps in information, as the evaluations of characteristics of those other AS is limited in terms of selectivity (i.e. target oriented products), persistence and mobility in the environment. It is important to remark again that this procedure does not pretend to be unaware of the environment hazards and human health risks associated and derived from use of those other than I, F, H or PGR substances.

Among those AS different to I, F, H o PGR that were removed from the list of the most applied products, it is possible to mention, that the soil sterilant 1,3-Dichlorpropene, which is employed in production of fruit trees in ES and BE, mineral oils (petroleum oils) coadjutants used to alleviate formulations and often applied in production of fruit trees in GR, ES, IT, PT and SI and in production of cereals in ES, NL and IT and the rodenticide Choline Chloride that is significantly used in production of cereals in IT.

Regarding the indicators used to evaluate the properties of AS, it is important to remark that they represent a potential hazardousness associated to those AS. To achieve an evaluation of the real effect on the environment, to human health and natural species, an assessment of the exposure is required. That exposure is related to climatic and technical conditions of application. However, as our interests are to value the harmfulness of the AS used in the production of cereals and fruit trees and then to compare the average score of the potential hazardousness generated from the use of those AS in the production of cereals or fruit trees among different countries, the use of the selected variables is appropriate.

3.2.2.3. Data Coverage

- **Countries**

The countries that are taken into consideration for the assessment of pesticide use innovation are the same ones, for which the pesticide use intensity was estimated. That means, in the production of cereals Luxembourg is annexed to BE and Bulgaria, Romania, Cypress and Malta are excluded. While for the production of fruit trees, besides the countries that are not included when evaluating production of cereals, CZ and EE are also leaved out. The composition of the crop group cereals and fruit trees and the significance of the production of wheat and apples within these groups respectively is mentioned in the section 3.1.1.3.

- **AS applied**

From the detailed list of AS applied in production of cereals and fruit trees during 2003, those AS other than I, F, H or PGR were removed for our analysis. Similarly, those AS, for which the availability of the variables, that have been chosen to assess pesticide use innovation, was limited, were excluded from the list to increase the accuracy of our estimations by reducing uncertainty in the existing information. Thus, in the calculations are only included those AS, for which in the worse of the cases, at least 75% of the information is available (i.e. for three variables of four). In the Annex 1, those AS that were applied in production of cereals in 2003 and their corresponding percentage relative to the total of I, F, H and PGR are listed in the Table 3. The Table 4 of the Annex 1 contains similar information for the production of fruit trees.

In terms of quantity of AS applied, for the production of cereals the list of AS selected correspond in average to 85% of the total amount of AS (I, F, H, and PGR) applied in 2003, the greatest percentages are found in EE and LT with 99% and in LT with 97%, while the lowest coverage correspond to SI (40%), DK (63%) and FR (78%). In the production of fruit trees, 89% of the total amount of I, F, H and PGR used in 2003 is represented by the AS selected. The highest coverage of AS is found in AT (99%), IE (99%) and LV (98%), and the lowest coverage in ES (68%), IT (80%) and BE (82%). In the Tables 6 and 7, the amount of AS that are included in the evaluation of the properties and characteristics of AS are listed and expressed in terms of percentage of total quantity of I, F, H and PGR that were applied in production of cereals and fruit trees respectively.

Table 6. Percentage of selected AS used in calculation of pesticide use innovation indicator relative to total quantity of I, F, H and PGR applied in production of cereals in 2003

	AT	**BE**	**CZ**	**DE**	**DK**	**EE**	**ES**	**FI**	**FR**	**GR**	**HU**	**IE**	**IT**	**LT**	**LV**	**NL**	**PL**	**PT**	**SE**	**SI**	**SK**	**UK**
%	90	79	93	84	64	99	90	90	78	91	80	79	91	99	97	90	94	86	85	40	93	85

Data source: Eurostat

Table 7. Percentage of selected AS used in calculation of pesticide use innovation indicator relative to total quantity of I, F, H and PGR applied in production of fruit trees in 2003

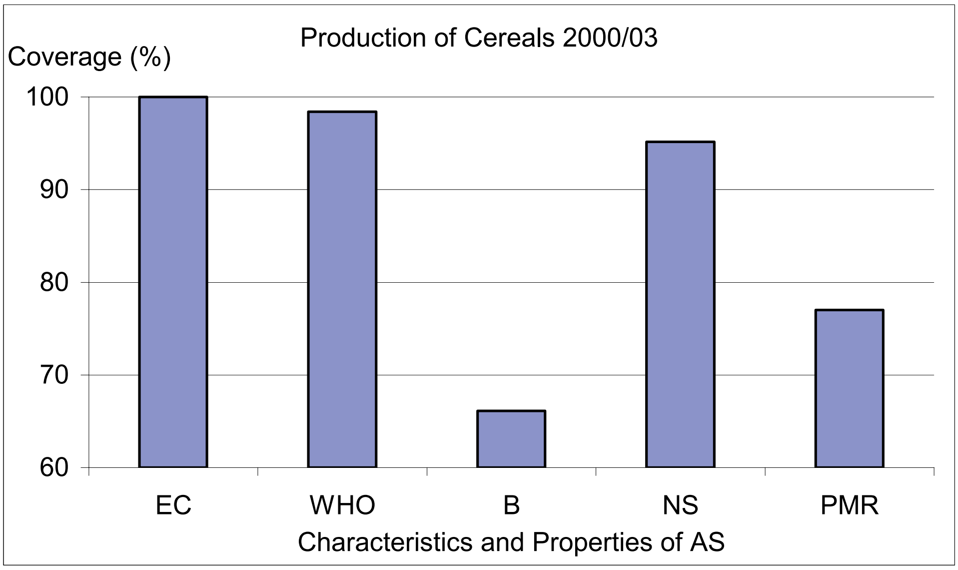
	AT	**BE**	**DE**	**DK**	**ES**	**FI**	**FR**	**GR**	**HU**	**IE**	**IT**	**LT**	**LV**	**NL**	**PL**	**PT**	**SE**	**SI**	**SK**	**UK**
%	99	81	91	97	68	92	86	90	91	98	80	96	98	83	92	83	91	84	91	96

Data source: Eurostat

- **Variables to assess AS characteristics and properties**

For the assessment of the characteristics and properties of those AS used during 2003 in the production of cereals, the information used to evaluate the variable regulatory status is available for all those AS, similarly an excellent coverage is obtained for valuation of the hazardousness for human health (98% of those AS) and toxicity to natural species (95% of those AS). A dissimilar situation occurs when evaluating side effects on beneficial organisms, because evaluations for only 66% of those AS are available. In Figure 7 the percentage of those AS, for which evaluations related to each variable chosen, are shown. (in the Figure 7, EC: regulatory status, WHO: hazardousness for human health, B: side effects on beneficial organisms, NS: toxicity for natural species and PMR: potential risk for groundwater)

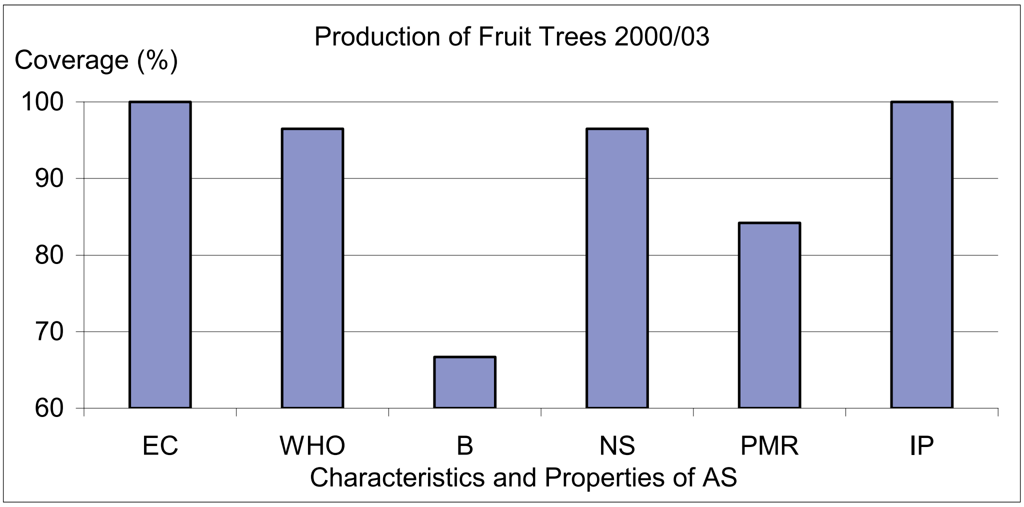
Figure 7. Availability of information to evaluate AS applied in the production of cereals.



Data sources: Eurostat, EC, WHO, IOBC, PAN, NPIC (own calculations)

For the AS applied in the production of fruit trees during 2003, the coverage of the variables selected to estimate AS safety is high in the case of regulatory status (100%), hazardousness for human health (97%) and toxicity for natural species (96%) and is low in the case of side effects on beneficial organisms (67%). The difference in the availability of information, when compared with the production of cereals is that the potential for groundwater is better covered (84% compared with 77%) and in addition in the selected list of AS, those ingredients that are prohibited (3%) or restricted (16%) to be used under IP are identified. In the Figure 8, the coverage of each variable in terms of percentage of AS evaluated, is depicted (in the Figure 8, EC: regulatory status, WHO: hazardousness for human health, B: side effects on beneficial organisms, NS: toxicity for natural species and PMR: potential risk for groundwater, IP: recommendations of use under IP).

Figure 8. Availability of information to evaluate AS applied in production of fruit trees.



Data sources: Eurostat, EC, WHO, IOBC, PAN, NPIC (own calculations)

3.2.2.4. Data Transformation

The information associated to each variable that has been selected to evaluate properties of AS is transformed into a comparable scale to aggregate them to an indicator of pesticide use innovation and also to avoid effects on the composite index generated by differences in scales of the variables used in the calculation. Therefore, for each variable, a scale between 0.1 and 1 is adapted, where 1 represents the highest degree of innovation and 0.1 the lowest one. The use of zero as the lowest value is avoided in the calculation of the indicator of pesticide use innovation, because multiplicative operations are included.

Accordingly, the following values are assigned for the different classes related to each variable: regulatory status (Table 8), hazardousness for human health (Table 9), side effects on beneficial organisms (Table 10), toxicity for natural species (Table 11), potential risk for groundwater (Table 12) and recommendations of AS use under IP (Table 13).

Table 8. Innovation score for the regulatory status of AS

Variable: Regulatory status		
AS on market (before/after 1993)	Status in annex 1 (Directive 91/414/ECC)	Innovation score
New	In	1
Old	In	0.67
Old	Pending	0.43
Old	Out	0.1

Data source: EC (2007)

Table 9. Innovation score for the hazardousness of AS use for human health

Variable: hazardousness for human health		
Class	Hazardousness	Innovation score
U	Unlikely	1
III	Slightly	0.775
II	Moderately	0.55
Ib	Highly	0.325
Ia	Extremely	0.1

Data source: WHO (2005)

Table 10. Innovation score to evaluate the side effects of AS use in beneficial organisms

Variable: side effects on beneficial organisms		
Class	Side effects	Innovation score
N	Harmless/slightly	1
M	Moderately	0.55
T	Harmful	0.1

Data source: IOBC (2002)

Table 11. Innovation score to evaluate the toxicity of AS for natural species

Variable: toxicity for natural species		
Class	Toxicity	Innovation score
N	Not acutely	1
S	Slightly	0.775
M	Moderately	0.55
H	Harmful	0.325
V	Very high	0.1
-	Absence	0.775
+	Presence	0.325

Data sources: IOBC, PAN (2002)

Table 12. Innovation score to evaluate the potential risk of AS use for groundwater

Variable: potential risk for groundwater		
Class	Pesticide Movement Rating	Innovation
E	Extremely low	1
VL	Very low	0.82
L	Low	0.64
M	Moderate	0.46
H	High	0.28
VH	Very high	0.1

Data source: NPIC (2005)

Table 13. Innovation score for AS that are prohibited or restricted under IP

Variable: recommendations of AS use under IP	
Recommendation for AS use	Innovation
No referenced	0.55
Restricted	0.44
Prohibited	0.1

Data source: IOBC (2002)

3.2.2.5. Aggregation of the variables

Based on the values assigned to each property or characteristic of an individual AS, an average score that corresponds to the assessment of its innovation is calculated. To calculate the average score for each AS, the weight assigned to each variable in the aggregation process is attained from the EOS. We have received 23 expert estimations of the importance that should be given to each variable. Table 14 shows the average weights for each variable according with the evaluations made by the group of Experts.

It is important to mention that in the assessment of the average score, the available information for each AS includes at least 4 variables (80%) for those products applied in the production of cereals and at least 5 variables (83%) for those pesticides applied in the production of fruit trees. In the case that information of one variable is missed, the value is not imputed and the average score is calculated with the information available.

Table 14. Average weights (in %) given to variables used to evaluate AS.

Production of Cereals						Production of Fruit Trees						
Variable	EC	WHO	B	NS	PMR	Variable	EC	WHO	B	NS	PMR	IP
Weight	22	24	20	18	16	Weight	21	23	17	14	12	13

EC: regulatory status, WHO: hazardousness for human health, B: side effects in beneficial organisms, NS: toxicity for natural species, PMR: potential risk for groundwater, IP: recommendations of use under IP

To estimate the innovation for each AS, all the variables are included and weighted according to values obtained from the experts opinions in order to determine the classification of agricultural systems that are taken as a reference in later analyses. Average scores obtained for each AS used in the production of cereals and fruit trees during 2003 are listed in the Tables 5 and 6 of the Annex 1 respectively under the columns called I1.

3.2.2.6. Sensitivity Analysis

- **Aggregation of Variables**

The importance of each variable included in the index is represented by the weight given. Among the techniques employed to decide the weight that should be assigned to each variable, it is possible to mention data-dependent statistical tools, judgment-based expert opinions and budget allocation schemes (Esty et al., 2005).

As we are neither experts in pesticides, nor in environmental sciences, we have conducted a survey on experts opinions for the judgement of the variables that we have selected for the building of the pesticide use innovation indicator. We have asked if the seven variables are suitable to assess pesticide use innovation, if other variables should be included and which relevance has each variable, when aggregating them in an indicator, by assigning a weighting factor. The results of the survey are summarized in the Annex 2.

From the commentaries and suggestions collected by the EOS, it is prudent to compare the estimation of innovation scores and its respective classification with two classifications, in which the variables included are specifically oriented to evaluate normative aspects and potential hazardousness.

For the evaluation of **normative aspects**, for each AS, an average score of innovation is estimated by considering its regulatory status and in the recommendations of use under IP (only for products applied in production of fruit trees). Thus, for AS applied in production of cereals the average score of innovation corresponds to the value of the variable regulatory status, while for products applied in production of fruit trees, the average score is calculated as the product of the values of the regulatory status (with a weight equal to 62%) and the recommendations of use under IP (with a weight equal to 38%). The importance given to each variable keeps the same relation given to these variables in the EOS.

The columns I2 of the Tables 5 and 6 of the Annex 1 include the average scores of normative aspects obtained for each AS used in production of cereals and fruit trees during 2003 respectively.

For the evaluation of the **potential hazardousness**, four variables are taken into account for the calculation of an average score for each AS, hazardousness for human health, side effects in beneficial organisms, toxicity for natural species and potential risk for groundwater. The weights assigned to each variable are derived from the results of the EOS and presented in the Table 15.

Table 15. Variable weights (in %) for calculation of potential hazardousness of AS

Variable	WHO	B	NS	PMR	
Weight	31	25	23	21	Production of Cereals
Weight	34	26	22	17	Production of Fruit Trees

WHO: hazardousness for human health, B: side effects in beneficial organisms, NS: toxicity for natural species, PMR: potential risk for groundwater

The average scores of each AS used in production of cereals and fruit trees during 2003 are included in the columns I3 in the Tables 5 and 6 of the Annex 1.

- **Imputation of missed values**

The existence of missing information increases the uncertainty of estimations and limits the accuracy of the evaluations. The imputation of missing data pursues to complete data gaps with plausible values and is an important step in the calculation of composite indices such as the innovation or characteristics and properties of an AS, knowing that the effect generated from use of incomplete information may be boosted when the information is aggregated.

For the imputation of missing information there are some statistical alternatives that are based on two main assumptions, one is that a data gap does not depend on the unobserved information and so it might be filled randomly and the other is that the missing information can be defined as a function of the existing observations or information, thus, the missing data can be estimated through an iterative calculation (Esty et al., 2005). However, it is important to remind that for the imputation of missing data that are defined by inherent characteristics such as chemical properties or climatic conditions, the predictors (e.g. existing observations) are limited, as the level of confidence and accuracy of the estimation is distrustful.

In this analysis, for the imputation of missing data two mechanisms are evaluated in respect to the initial estimation of average scores (without imputation). These mechanisms are the imputation of data by means of averages of existing observations and the imputation of data by replacing gaps with the median value of the transformation scale.

Using Average imputation it is assumed that the missing data of a variable have a value equivalent to the average innovation score of those AS belonging to the same chemical class (e.g. H organophosphorus). In the case that not enough scientific evidence is available (i.e.

adequate number of existing observations), the average value of the corresponding pesticide group (i.e. I, F, H, PGR) is assigned to fill the data gap.

Table 16. Averages used to impute missing data for AS used in production of cereals

Variable	WHO	B	NS	PMR
Average of	H	F	H	F
		F/conazole	H/phenoxy	F/conazole
		H	I	H
		I		H/phenoxy
		I/organophosphorus		Total
		Total		

WHO: hazardousness for human health, B: side effects on beneficial organisms, NS: toxicity to natural species, PMR: potential risk for groundwater

For the AS applied in the production of cereals in 2003, the imputation of missing values for specific variables of an AS (see Table 5 in the annex 1) is assigned according to averages listed in the Table 16. Similarly, for AS applied in the production of fruit trees in 2003, missing data (see Table 6 in Annex 1) are replaced with averages of the corresponding chemical classes or types as indicated in the Table 17

Table 17. Averages used to impute missing data for AS used in production of fruit trees

Variable	WHO	B	NS	PMR
Average of	I	F	H	F
		F/conazole		H
		F/dithiocarbamate		I
		H		
		I		
		I/organophosphorus		

WHO: hazardousness for human health, B: side effects on beneficial organisms, NS: toxicity to natural species, PMR: potential risk for groundwater

The Tables 5 and 6 of the Annexe 1 include under the column I4 the corresponding average scores of each AS applied in production of cereals and fruit trees resulting from the average imputation of missing data.

Using Median imputation, the missing information is considered neutral in terms of innovation and consequently, the imputation process is completed by assigning to the missing values an innovation grade of 0.55, which corresponds to the median value of the transformation scale, which has been previously implemented (when transforming variables classes into comparable scale from 0.1 to 1).

The columns I5 of the Tables 5 and 6 in the Annexe 1 contain the average score for each AS used in the production of cereals and fruit trees when applying the median imputation mechanism.

3.2.2.7. Pesticide Use Innovation at country and European average

- **Pesticide Use Innovation at country level**

The pesticide use innovation for different countries of the EU is calculated through valuation of normative aspects and potential hazardousness of those products that are applied in crop production and specifically, in this analysis, in the growing of the crop groups cereals and

fruit tress during 2003. For the calculation of an indicator of Pesticide Use Innovation in one country, four elements or set of information are required:

i. Choosing variables to assess innovation according with the properties and characteristics of AS and transformation of evaluations of these variables into a comparable scale.
ii. Obtaining a list of F, I, H,and PGR that area applied in crop production, for which the evaluation of characteristics and properties is available with a modest level of missing information (i.e. existence of at least 75% of the information and evaluations) and imputation of missing values.
iii. Assessing an average score for each AS that is taken into account for the evaluation.
iv. Estimation of the proportion of AS that is applied in crop production relative to the total amount of pesticides (F, I, H and PGR) that are used (i.e. percentage of the dosage)

Thus, for one country, the pesticide use innovation indicator is calculated as the sum-up of the products of the average score of innovation of each AS and their corresponding percentages within the total amount of pesticides applied.

- **European average of Pesticide Use Innovation**

The indicator of pesticide use innovation for one country could be interpreted as the valuation of one individual average product rated with a determined score. For that reason when comparing the innovation in pesticide use among different countries of the EU, it is necessary to consider that those hypothetical average products are not applied in the same proportion.

The average of the pesticide use innovation indicator for all European countries is weighted with the area under cultivation and determines the division of the high and low innovation classes. This value is corrected according with the potential application, which is associated with the extension of the area under production. Thus, the indicator of pesticide use innovation of one country will influence more the European average (i.e. breakpoint between high and low pesticide use innovation), if the area under production in that country is large and vice versa.

The weighted (corrected) European average for pesticide use innovation is obtained through dividing the sum up of the products of each national innovation score and the corresponding area under production by the total area under crop production in the EU.

For the production of cereals in the EU during 2003, the indicator of pesticide use innovation at national level is calculated as the sum up of the multiplication of the scores attained for each AS applied in crop growing (listed in the column I1 of Table 5 in the Annex 1) by the percentage of the total dose used that those AS represent (included in the Table 3 of the Annex 1). Similarly, for the production of fruit trees during 2003 in different countries of the EU, national values of pesticide use innovation are estimated as the sum up of the product of scores of AS applied (column I1 in the Table 6 of the Annex 1) and proportion of AS applied relative to the total amount of pesticides used (Table 4 of the Annex 1).

Table 18 encloses the values of pesticide use innovation at national level for the production of cereals and fruit trees during 2003, as well as the weighted (with the area under production) European averages for each crop group.

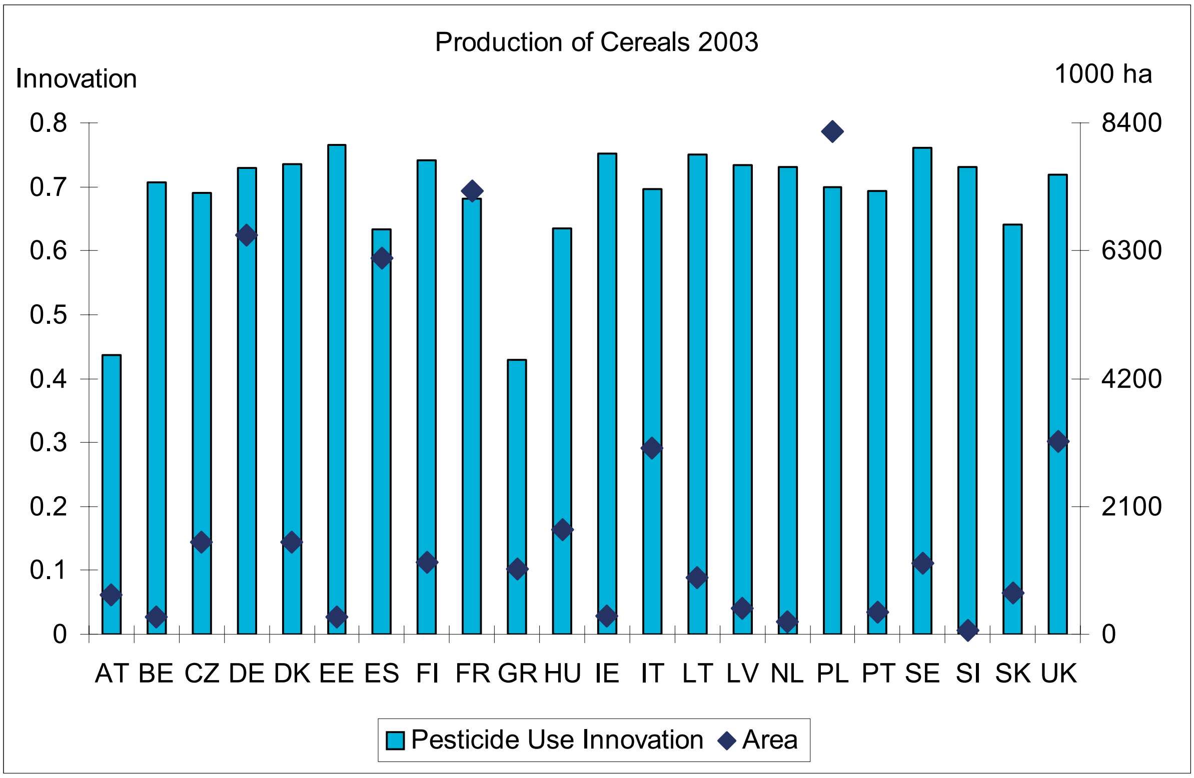
Table 18. Pesticide use innovation indicators in production of cereals and fruit trees in 2003.

CEREALS				**FRUIT TREES**			
Country	**Indicator for Pesticide use innovation**	**Country**	**Indicator for Pesticide use innovation**	**Country**	**Indicator for Pesticide use innovation**	**Country**	**Indicator for Pesticide use innovation**
AT	0.4368	**IE**	0.7524	**AT**	0.6319	**IT**	0.5869
BE	0.7074	**IT**	0.6969	**BE**	0.6371	**LT**	0.6218
CZ	0.6911	**LT**	0.7506	**DE**	0.6306	**LV**	0.6513
DE	0.7287	**LV**	0.7336	**DK**	0.6572	**NL**	0.6543
DK	0.7359	**NL**	0.7314	**ES**	0.5868	**PL**	0.6431
EE	0.7654	**PL**	0.6987	**FI**	0.6610	**PT**	0.6104
ES	0.6336	**PT**	0.6938	**FR**	0.6303	**SE**	0.6915
FI	0.7420	**SE**	0.7604	**GR**	0.5551	**SI**	0.5506
FR	0.6820	**SI**	0.7308	**HU**	0.6230	**SK**	0.6252
GR	0.4298	**SK**	0.6416	**IE**	0.7249	**UK**	0.6160
HU	0.6344	**UK**	0.7194				
Weighted average: 0.685				**Weighted average: 0.579**			

Pesticide use innovation scale: 1: very innovative; 0.1: not innovative

Data sources: EC, WHO, IOBC, PAN, NPIC (own calculations)

Figure 9. Innovation of AS applied and crop areas in production of cereals during 2003.

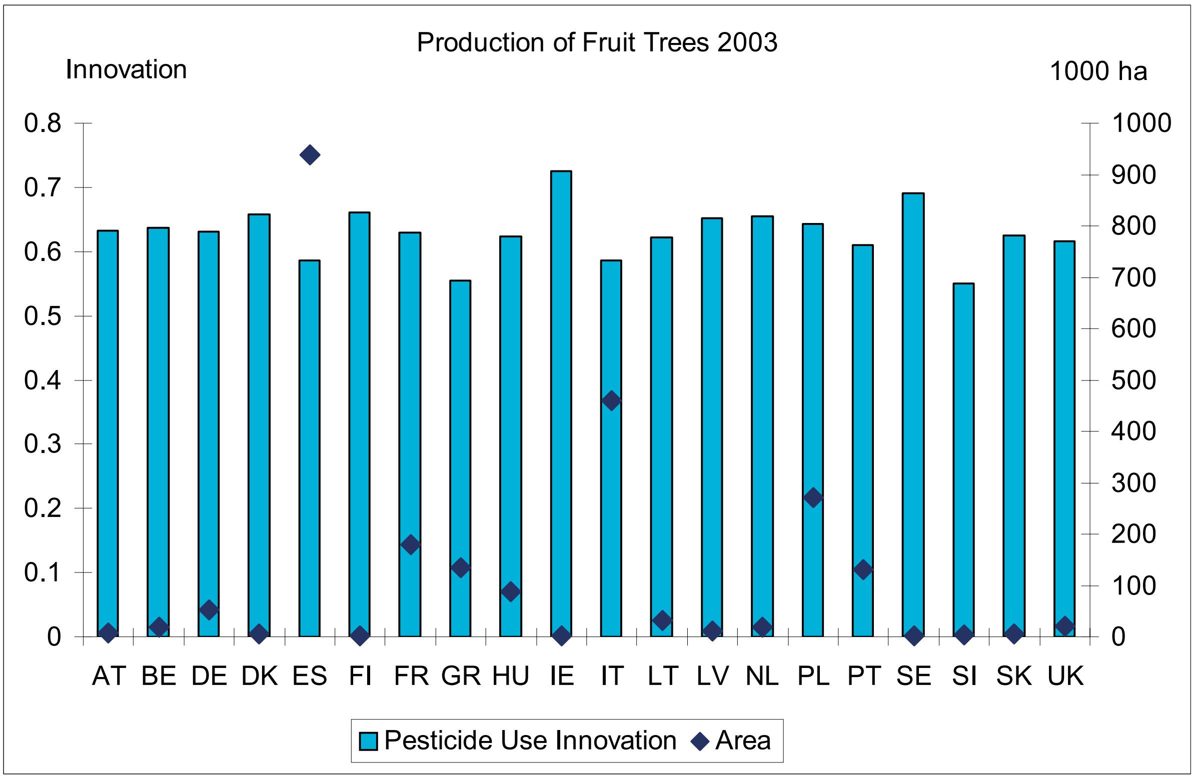


Data sources: EC, WHO, IOBC, PAN, NPIC (own calculations)

In 2003, the largest areas grown with cereals were located in PL, FR, DE, ES and UK, consequently, these countries exerted a strong influence in the European average of pesticide use innovation. From the nations with the highest values of pesticide use innovation (EE, SE, IE, LT and FI), none influences considerably the European average. Both situations are observable in the Figure 9, where the crop growing areas and an values of pesticide use innovation in production of cereals in 2003 are illustrated.

In the production of fruit trees during 2003, the countries with the largest areas harvested were ES, IT, PL, FR, GR, PT and HU. That means that the pesticide use innovation values attained for these nations influence more the European average. While, the nations with the highest values of pesticide use innovation were IE, SE, FI, DK and NL. In the Figure 10, the harvested areas and the pesticide use innovation values for the production of fruit trees during 2003 are depicted.

Figure 10. Innovation of AS applied and crop areas in production of fruit trees during 2003.



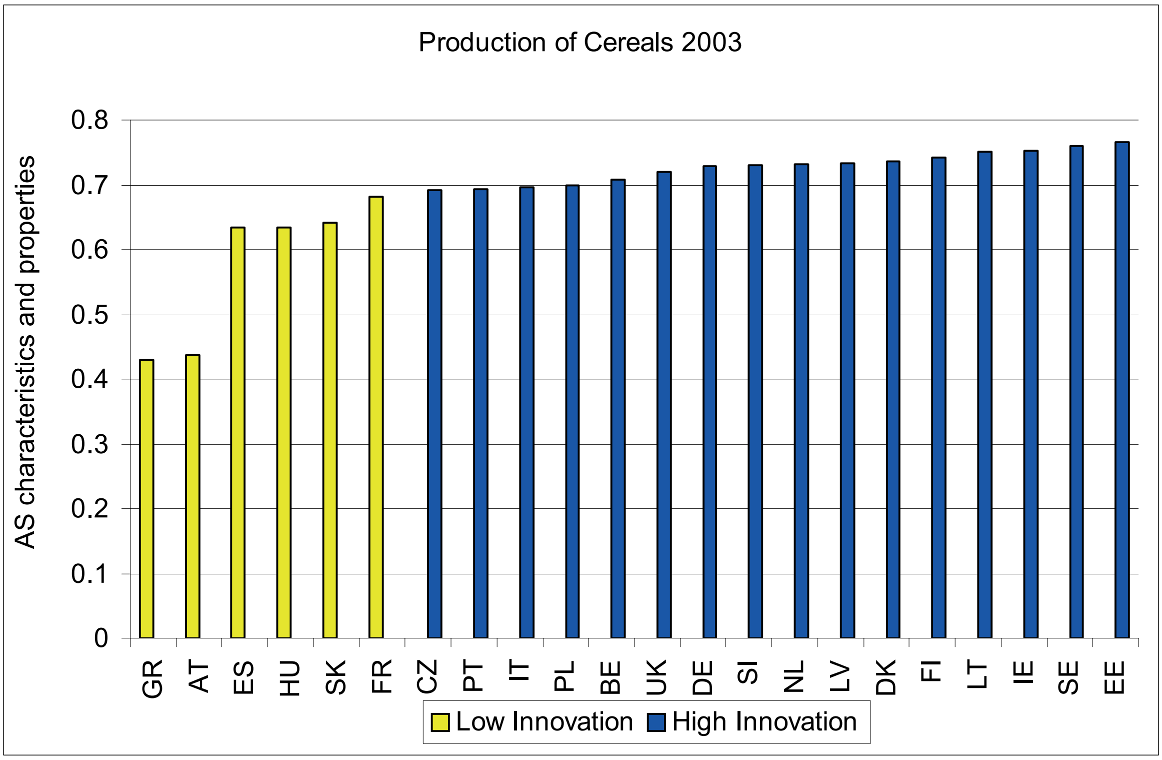
Data sources: EC, WHO, IOBC, PAN, NPIC (own calculations)

The classification of pesticide use intensity based on properties and characteristics of the AS applied in crop production in different countries of the EU during 2003 is presented in Figure 11 for cereal growing and in the Figure 12 for the production of fruit trees. In these graphics, the yellow columns represent those countries characterised by low levels of pesticide use innovation, while the blue columns correspond to these nations with a high level of pesticide use innovation.

It is remarkable that only 6 nations (27 %) were catalogued as having low pesticide use innovation levels in the production of cereals in 2003. Among those six countries, the values of pesticide use innovation calculated for GR and AT are very low, 0.43 and 0.44, respectively.

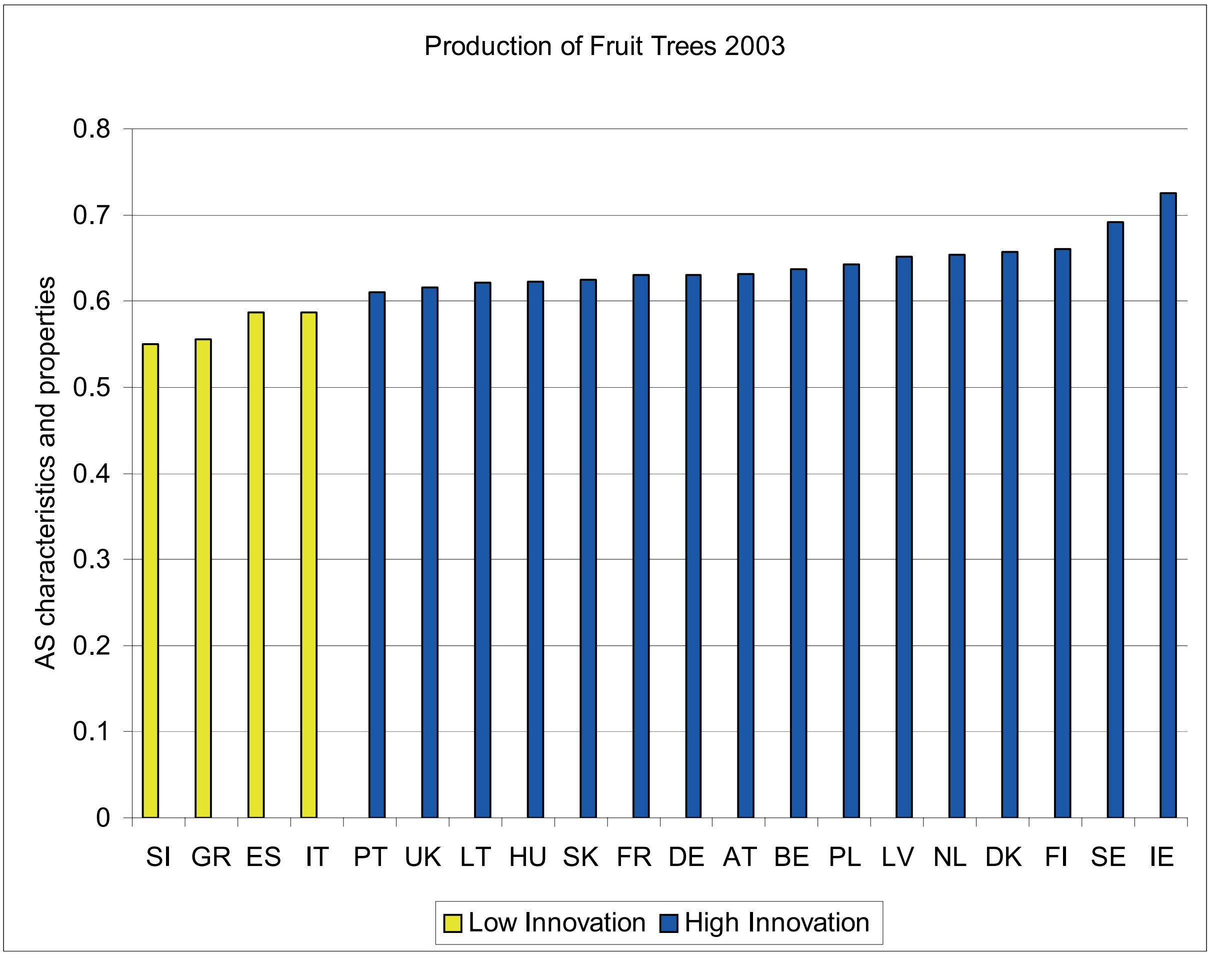
In Figure 11, it is observable that the European average of pesticide use innovation was equal to 0.69, the pesticide use innovation values in EE (0.77), SE (0.76), IE (0.75) and LT (0.75) correspond to the highest levels obtained and the variation of the pesticide use innovation values within the high level group present a slight increasing tendency.

Figure 11. Pesticide use innovation in production of cereals in 2003



Data sources: EC, WHO, IOBC, PAN, NPIC (own calculation)

Figure 12. Pesticide use innovation in production of fruit trees in 2003



Data sources: EC, WHO, IOBC, PAN, NPIC (own calculation)

Only four countries (20 %) were classified as having a low pesticide use innovation level in production of fruit trees during 2003. In Figure 12 the considerable variations of the innovation values within both low and high innovation classes are noticeable. The highest pesticide use innovation values corresponded to IE (0.72) and SE (0.69), the lowest levels were found in SI (0.55) and GR (0.56) and the European average of pesticide use innovation was equivalent to 0.60.

4. Results

4.1. Classification (evolution) of Agricultural Systems

4.1.1. Production of cereals (case study crop wheat)

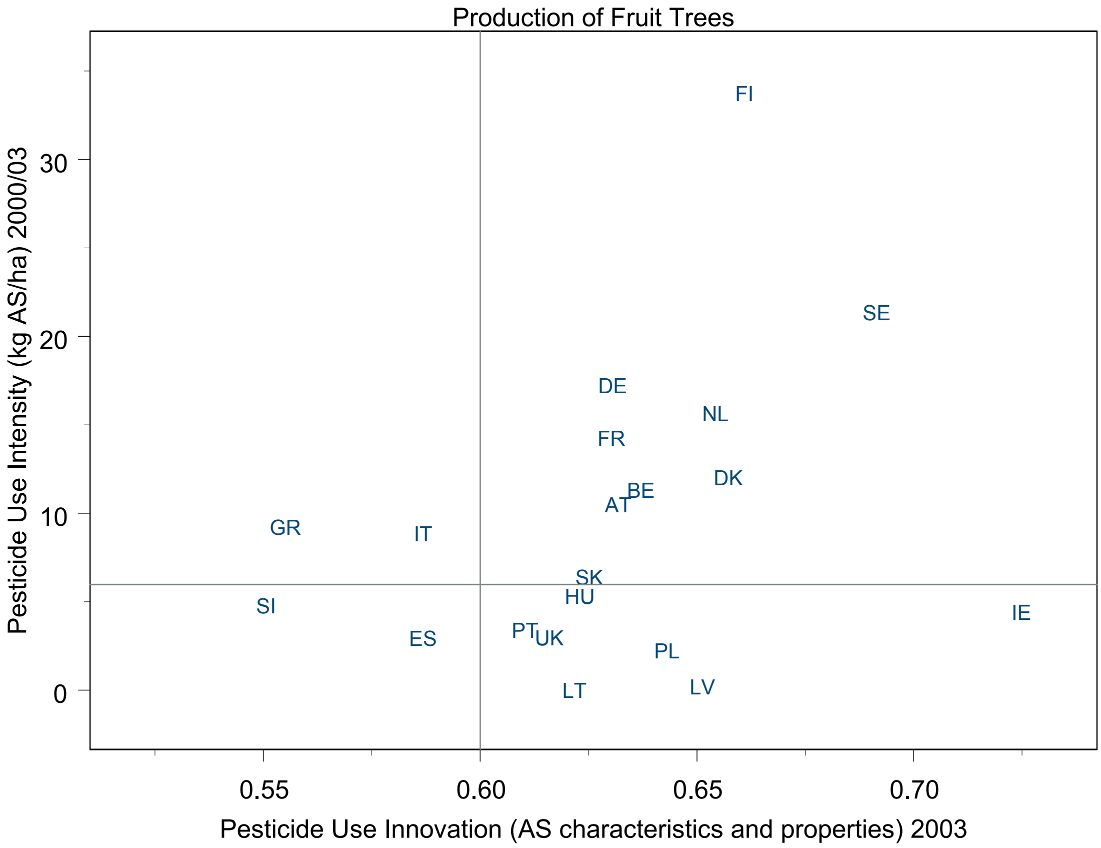
Figure 13. Agricultural systems implemented for production of cereals in the EU

In the Figure 13, the implementation of agricultural systems, which are classified according to pesticide use intensity and innovation (as defined in the section 2.1.1.) is observable for the production of cereals in the EU. Only one country (FR) was allocated in the upper-left quadrant that represents the *traditional farming system*, which is mainly dependent on the use of chemical inputs. A *modern farming scheme* for the production of cereals, which is characterised by high use of inputs and achievement of high yields is performed in NL, BE, UK, IE, and DE.

An *extensive agricultural production* characterised by low use of inputs and implementation of management strategies that make possible to reduce use of pesticides is carried out in five EU countries (GR, AT, ES, HU and SK). While, the *eco-friendly agricultural system* of production is performed in eleven countries: CZ, PT, PL, IT, SI, LV, DK, FI, LT, SE and EE.

4.1.2. Production of fruit trees

Figure 14. Agricultural systems implemented for production of fruit trees in the EU



In Figure 14, the classification of the four agricultural systems that are currently implemented for the production of fruit trees in the EU is illustrated. These four agricultural systems are defined through assessment of use of pesticides in crop production in terms of intensity and innovation.

In GR and IT, the production of fruit trees is characterised by a high level intensity in use of pesticides, which is aimed to obtain high yields, the innovation on pesticide use is considered as low and their production represent the *traditional farming.*

The *modern farming system*, which also pursues to achieve high crop yields and is associated with high intensity on use of pesticides, but with high innovation is related to production of fruit trees in SK, DE, FR, AT, BE, NL, DK, FI and SE.

In SI and ES, the production of fruit trees is performed under an *extensive agriculture* systems, that means that the use of pesticides in terms of both, intensity and innovation is low and the achievement of a production (in terms of tons) comparable with those obtained under traditional and modern farming systems, strongly depends on increments in harvested area.

The *eco-friendly agriculture* or production of fruit trees, that is less injurious for the environment, as the application of pesticides is low in intensity and high in innovation, is represented by the crop growing practices completed in PT, UK, LT, HU, PL, LV and IE.

4.2. Robustness of the Classification – Sensitivity Analysis

4.2.1. Aggregation of Variables

As explained in the Section 2.2.2.6., possible changes in the classification of agricultural systems are analysed when the variables employed to evaluate pesticide use innovation are aggregated to evaluate **normative aspects** and **potential hazardousness** associated to AS applied in production of cereals and fruit trees.

4.2.1.1. Production of cereals

In Table 19, pesticide use innovation values for production of cereals resulting from aggregation of five variables with the weights obtained through the EOS (column called: experts) are compared with the valuations of pesticide use innovation corresponding to calculations of normative aspects (column called: authorisation), for which only the variable regulatory status is taken into account, and potential hazardousness (column called: hazardousness) for which hazardousness for human health, side effects on beneficial organisms, toxicity for natural species and potential risk for groundwater are considered.

The European average is reduced when evaluating normative aspects (from 0.6856 to 0.6136) and is increased when assessing potential hazardousness of the AS applied in production of cereals (from 0,6856 to 0.7170). As the pesticide use innovation level changes for seven countries when evaluating normative aspects and for two countries when evaluating potential hazardousness, it is possible to assert that the use of the variable regulatory status involves a stability of 68.2 % (or uncertainty of 31.8%), while by taking into account the hazardousness for human health, side effects on beneficial organisms, toxicity for natural species and potential risk for ground water, an uncertainty of 9.1% (or stability of 90.9%) is enclosed.

In the Table 19, countries belonging to low level pesticide use innovation have a negative value in the columns “Level”. Those values that signify a change in the pesticide use innovation level (respect to the inclusion of five variables and weighted with the average estimations collected with the EOS) are indicated with a yellow mark. For the evaluation of the normative aspects, the position of BE, CZ, DE, ES, LV, SK and UK is changed, while in the estimation of the potential hazardousness, only the allocation of FR and IT varies.

Table 19. Variation in pesticide use innovation values for production of cereals when changing aggregation of variables

	Experts		Authorisation		Hazardousness	
	Innovation	Level	Innovation	Level	Innovation	Level
AT	0.4368	-0.2489	0.5811	-0.0325	0.4634	-0.2535
BE	0.7074	0.0218	0.6001	-0.0135	0.7559	0.0390
CZ	0.6911	0.0055	0.5836	-0.0299	0.7283	0.0113
DE	0.7287	0.0431	0.6032	-0.0104	0.7719	0.0549
DK	0.7359	0.0503	0.6470	0.0334	0.7626	0.0456
EE	0.7654	0.0797	0.6498	0.0363	0.8002	0.0832

ES	0.6336	-0.0520	0.6399	0.0263	0.6493	-0.0677
FI	0.7420	0.0564	0.6464	0.0329	0.7694	0.0524
FR	0.6820	-0.0036	0.5741	-0.0395	0.7284	0.0114
GR	0.4298	-0.2559	0.6051	-0.0085	0.4469	-0.2701
HU	0.6344	-0.0512	0.5898	-0.0237	0.6527	-0.0642
IE	0.7524	0.0668	0.6462	0.0326	0.7860	0.0690
IT	0.6969	0.0112	0.6539	0.0404	0.7133	-0.0037
LT	0.7506	0.0649	0.6583	0.0447	0.7784	0.0614
LV	0.7336	0.0480	0.5929	-0.0206	0.7799	0.0629
NL	0.7314	0.0458	0.6583	0.0448	0.7550	0.0380
PL	0.6987	0.0131	0.6203	0.0067	0.7243	0.0074
PT	0.6938	0.0082	0.6189	0.0053	0.7221	0.0051
SE	0.7604	0.0748	0.6682	0.0546	0.7869	0.0699
SI	0.7308	0.0451	0.6300	0.0164	0.7656	0.0486
SK	0.6416	-0.0440	0.6396	0.0260	0.6451	-0.0719
UK	0.7194	0.0338	0.5827	-0.0309	0.7708	0.0538
European average	**0.6856**		**0.6136**		**0.7170**	

4.2.1.2. Production of fruit trees

Pesticide use innovation values for the production of fruit trees are included in the Table 20. Under the column "Experts", the results of the aggregation of six variables with the weights taken from the EOS are listed. In the column "Authorisation", pesticide use innovation values resulting from the combination of scores assigned to the regulatory status and the recommendations of use under IP are presented. The aggregation of potential hazards for human health, beneficial organisms, natural species and groundwater is included in the column "Hazardousness".

The European average is reduced when evaluating normative aspects (from 0.6000 to 0.5079) and is increased when assessing potential hazardousness of the AS applied in production of cereals (from 0,6000 to 0.6491). The pesticide use innovation level changes for two countries (FR and IT) when evaluating normative aspects and for one country (LT) when evaluating potential hazardousness. It means that evaluation of normative aspects has an uncertainty equal to 10% (or stability equal to 90%), while the stability of the assessment of potential hazardousness is equivalent to 95% (or the uncertainty is equal to 5%).

Countries belonging to the high level of pesticide use innovation have a positive value in the columns "Level" of the Table 20. Those values, for which the pesticide use innovation level changes (respect to the inclusion of six variables and weighted with the average estimations collected with the EOS) are marked in yellow.

Table 20. Variation in pesticide use innovation values for production of fruit trees when changing aggregation of variables

	Experts		Authorisation		Hazardousness	
	Innovation	Level	Innovation	Level	Innovation	Level
AT	0.6319	0.0319	0.5525	0.0446	0.6642	0.0151
BE	0.6371	0.0371	0.5456	0.0377	0.6831	0.0340
DE	0.6306	0.0306	0.5096	0.0017	0.6876	0.0385
DK	0.6572	0.0572	0.5710	0.0631	0.6941	0.0450
ES	0.5868	-0.0133	0.4904	-0.0175	0.6434	-0.0057
FI	0.6610	0.0610	0.6124	0.1045	0.6847	0.0356

FR	0.6303	0.0302	0.5060	-0.0019	0.6864	0.0374
GR	0.5551	-0.0449	0.4240	-0.0839	0.6195	-0.0296
HU	0.6230	0.0229	0.5194	0.0115	0.6664	0.0173
IE	0.7249	0.1249	0.7935	0.2856	0.6713	0.0222
IT	0.5869	-0.0131	0.5183	0.0104	0.6173	-0.0318
LT	0.6218	0.0218	0.5822	0.0742	0.6464	-0.0027
LV	0.6513	0.0513	0.5685	0.0605	0.6878	0.0387
NL	0.6543	0.0543	0.5700	0.0621	0.6935	0.0444
PL	0.6431	0.0431	0.5672	0.0593	0.6887	0.0396
PT	0.6104	0.0104	0.5259	0.0180	0.6587	0.0096
SE	0.6915	0.0914	0.5875	0.0795	0.7441	0.0950
SI	0.5506	-0.0494	0.4498	-0.0582	0.6097	-0.0394
SK	0.6252	0.0252	0.5251	0.0171	0.6716	0.0225
UK	0.6160	0.0160	0.5252	0.0173	0.6649	0.0159
European average	**0.6000**		**0.5079**		**0.6491**	

4.2.2. Imputation of missing values

The main source of uncertainty for the classification of agricultural systems based on pesticide use parameters is generated by the use of variables, for which some information is missed. In the section 3.1.2.5., two imputation techniques to overtake this problematic are proposed (*average imputation:* replacing missing information with the average value of the respective chemical class or pesticide group and *median imputation*: assigning the median value of the transformation scale to the information gaps)

4.2.2.1. Production of cereals

The Table 21 contains the pesticide use innovation values obtained when the average and median imputation procedures are employed. Under the column "Levels" in the Table 21, negative ciphers indicate that the country is positioned in the low level of pesticide use innovation (and vice versa). Changes in the pesticide use innovation level are indicated with a green mark in the Table 21.

The European average of pesticide use innovation values for production of cereals is increased when both imputation techniques are put into operation (from 0.6856 to 0.7106 for the average imputation and to 0.6967 for the median imputation). Similarly, for both imputation mechanisms, the uncertainty is equal to 9% (or they have a stability of 91%). That means, only two for two countries, CZ and PL, there is a reallocation within the pesticide use intensity levels.

Table 21. Effects of imputation of missing data in pesticide use innovation values for production of cereals

	Experts		Average		Median	
	Innovation	Level	Innovation	Level	Innovation	Level
AT	0.4368	-0.2489	0.6643	-0.0463	0.6225	-0.0742
BE	0.7074	0.0218	0.7183	0.0077	0.7091	0.0124
CZ	0.6911	0.0055	0.6943	-0.0163	0.6814	-0.0153
DE	0.7287	0.0431	0.7155	0.0049	0.7078	0.0111
DK	0.7359	0.0503	0.7405	0.0299	0.7267	0.0300
EE	0.7654	0.0797	0.7653	0.0547	0.7653	0.0686

ES	0.6336	-0.0520	0.7076	-0.0030	0.6914	-0.0053
FI	0.7420	0.0564	0.7482	0.0376	0.7360	0.0393
FR	0.6820	-0.0036	0.7062	-0.0044	0.6932	-0.0035
GR	0.4298	-0.2559	0.6777	-0.0330	0.6401	-0.0566
HU	0.6344	-0.0512	0.6525	-0.0581	0.6435	-0.0532
IE	0.7524	0.0668	0.7414	0.0308	0.7401	0.0434
IT	0.6969	0.0112	0.7207	0.0101	0.7084	0.0117
LT	0.7506	0.0649	0.7505	0.0398	0.7504	0.0537
LV	0.7336	0.0480	0.7406	0.0300	0.7297	0.0330
NL	0.7314	0.0458	0.7323	0.0216	0.7173	0.0206
PL	0.6987	0.0131	0.7024	-0.0082	0.6856	-0.0111
PT	0.6938	0.0082	0.7298	0.0192	0.7009	0.0042
SE	0.7604	0.0748	0.7586	0.0480	0.7468	0.0501
SI	0.7308	0.0451	0.7126	0.0020	0.7119	0.0152
SK	0.6416	-0.0440	0.6739	-0.0367	0.6506	-0.0461
UK	0.7194	0.0338	0.7226	0.0120	0.7090	0.0123
European average	**0.6856**		**0.7106**		**0.6967**	

4.2.2.2. Production of fruit trees

In the Table 22, the values of pesticide use innovation of production of fruit trees that result from the application of two mechanisms of imputation of missing information are summarised. A classification in the high (low) level of pesticide use is represented by a positive (negative) number in the column "Level".

The European averages of pesticide use innovation increase when the average and the median imputation procedures are applied, from 0.6000 to 0.6171 and 0.6118 respectively. In both cases only UK suffers a change in the level of pesticide use innovation. The stability (uncertainty) of the imputation mechanisms is equal to 95% (5%). In the Table 22, the changes of UK in the pesticide use innovation levels are marked with a green sign.

Table 22. Effects of imputation of missing data in pesticide use innovation values for production of fruit trees

	Experts		Average		Median	
	Innovation	Level	Innovation	Level	Innovation	Level
AT	0.6319	0.0319	0.6318	0.0146	0.6311	0.0193
BE	0.6371	0.0371	0.6395	0.0223	0.6366	0.0248
DE	0.6306	0.0306	0.6362	0.0191	0.6345	0.0227
DK	0.6572	0.0572	0.6552	0.0381	0.6540	0.0422
ES	0.5868	-0.0133	0.6115	-0.0057	0.6050	-0.0068
FI	0.6610	0.0610	0.6591	0.0419	0.6497	0.0379

FR	0.6303	0.0302	0.6349	0.0177	0.6339	0.0221
GR	0.5551	-0.0449	0.5700	-0.0471	0.5642	-0.0476
HU	0.6230	0.0229	0.6233	0.0062	0.6227	0.0109
IE	0.7249	0.1249	0.7564	0.1392	0.6876	0.0759
IT	0.5869	-0.0131	0.6009	-0.0162	0.5951	-0.0167
LT	0.6218	0.0218	0.6504	0.0333	0.6458	0.0340
LV	0.6513	0.0513	0.6507	0.0336	0.6498	0.0380
NL	0.6543	0.0543	0.6546	0.0375	0.6532	0.0414
PL	0.6431	0.0431	0.6550	0.0378	0.6486	0.0368
PT	0.6104	0.0104	0.6353	0.0181	0.6305	0.0187
SE	0.6915	0.0914	0.6844	0.0673	0.6799	0.0681
SI	0.5506	-0.0494	0.5854	-0.0318	0.5784	-0.0334
SK	0.6252	0.0252	0.6383	0.0211	0.6361	0.0244
UK	0.6160	0.0160	0.6159	-0.0012	0.6116	-0.0001
European average	**0.6000**		**0.6171**		**0.6118**	

4.3. Importance of the agricultural systems implemented to grow crops in the EU

In this section, the importance of each agricultural system is evaluated with the share in area harvested and quantity produced relative to the total European amounts. For this analysis, averages values for the case study crops "wheat" and "apple" are used.

4.3.1. Production of cereals (case study crop wheat)

In Figure 15, the percentages of area harvested and quantity of wheat produced in different countries of the EU between 2003 and 2006 are illustrated and distributed in four agricultural systems, where the red column stand for traditional farming, modern farming is represented by the blue columns, the extensive agriculture correspond to the yellow columns and the green columns symbolize the eco-friendly agriculture.

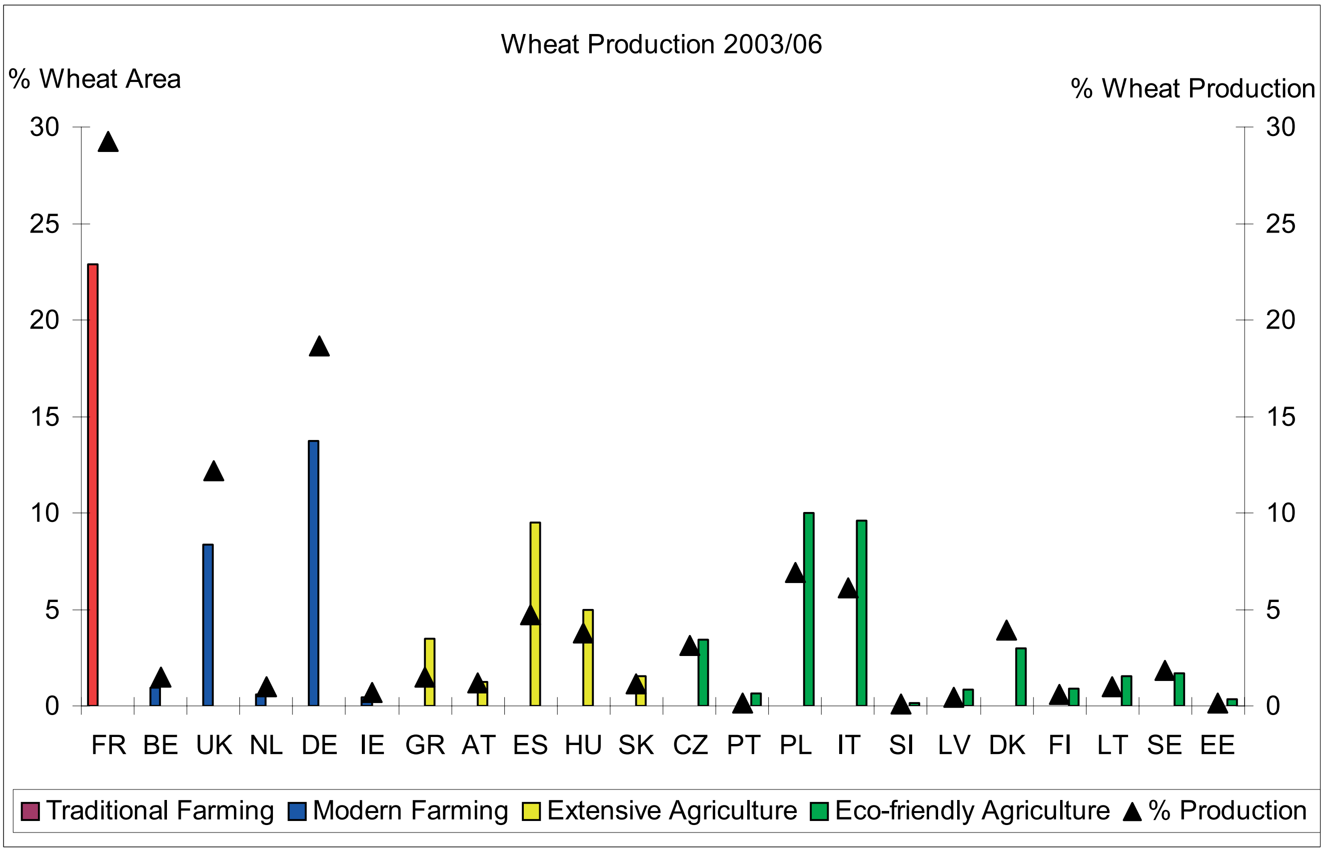
Under traditional and modern farming system, the participation in production of wheat is higher than the participation in area under production (the black triangles are located in a higher position than the red and blue columns). The attainment of higher yields is the reason why the share in production of this agricultural system is significant. It is also remarkable that the largest share of the area under wheat production correspond to this modern farming system.

Apparently, for systems characterised by high intensity in pesticide use (traditional and modern farming), the participation in production of wheat is positively influenced by the percentage of area harvested, for the countries with the largest share in area under production (FR, DE and UK), the spot representing the percentage of production is visibly more separated that for the countries with low share area under production (BE, NL and IE). This situation may suggest that in crop production, some type of specialisation is boosted when increasing areas under production.

Unlikely, for agricultural systems characterised by low intensity in use of pesticides, the largest the area harvested (higher columns) is, the lower the percentage of quantity produced (deeper position of the spot inside the column) is. It is also important to mention that the implementation of the eco-friendly agricultural system (in terms of area) has an important participation in the production of wheat.

In the representation of agricultural systems characterised by low intensity in use of pesticides (extensive and eco-friendly agriculture), the spot corresponding to the percentage of production lays inside of the yellow and green columns (excepting for DK and SE). This condition confirms the statement that crop outputs obtained (in absolute terms) under low intensity agricultural systems, are only comparable with those quantities produced under high intensity agricultural systems, if the harvested area is enlarged.

Figure 15. Agricultural systems used to produce wheat in the EU between 2003 and 2006

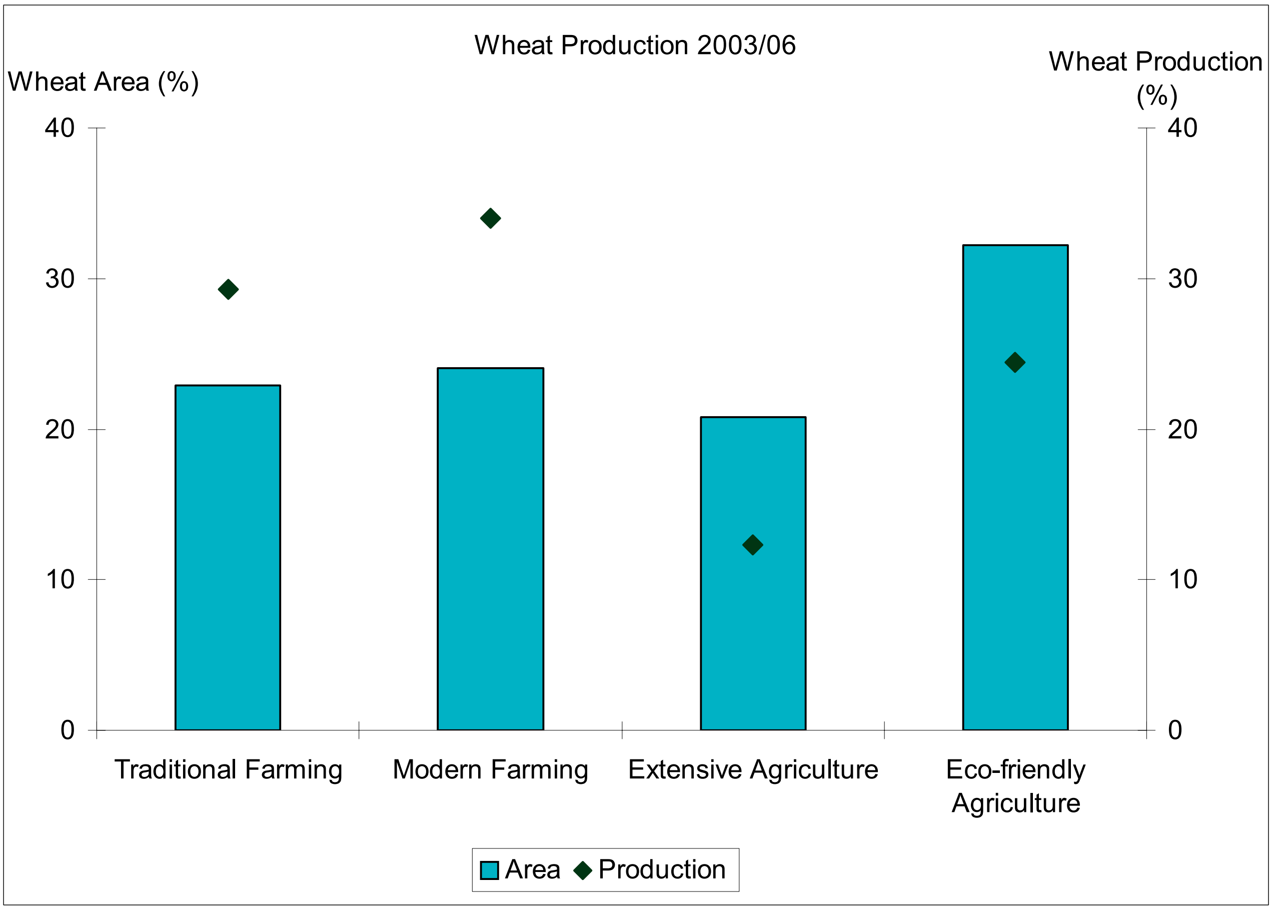


Data source: FAO

The corresponding harvested area occupied and crop output produced under each agricultural systems for the production of wheat between 2003 and 2006 in the EU are illustrated in the Figure 16.

In the Figure 16 is noticeable that in terms of area, the most important agricultural system implemented for the production of wheat in the EU is the eco-friendly agriculture (32.2% of the EU area). It is also observable that a higher productivity is achieved under schemes of production characterised by high level of pesticide use innovation for both cases, high and low intensity pesticide use (i.e. higher percentage of production in modern faring 34% and eco-friendly agriculture 24.4% than in traditional farming 29.3% and extensive agriculture 12.3% respectively). However, in the EU the major percentage of wheat is produced under traditional and modern farming (i.e. high intensity in pesticide use).

Figure 16. Corresponding areas and productions of wheat among agricultural systems



Data source: FAO

4.3.2. Production of fruit trees (case study crop: apple)

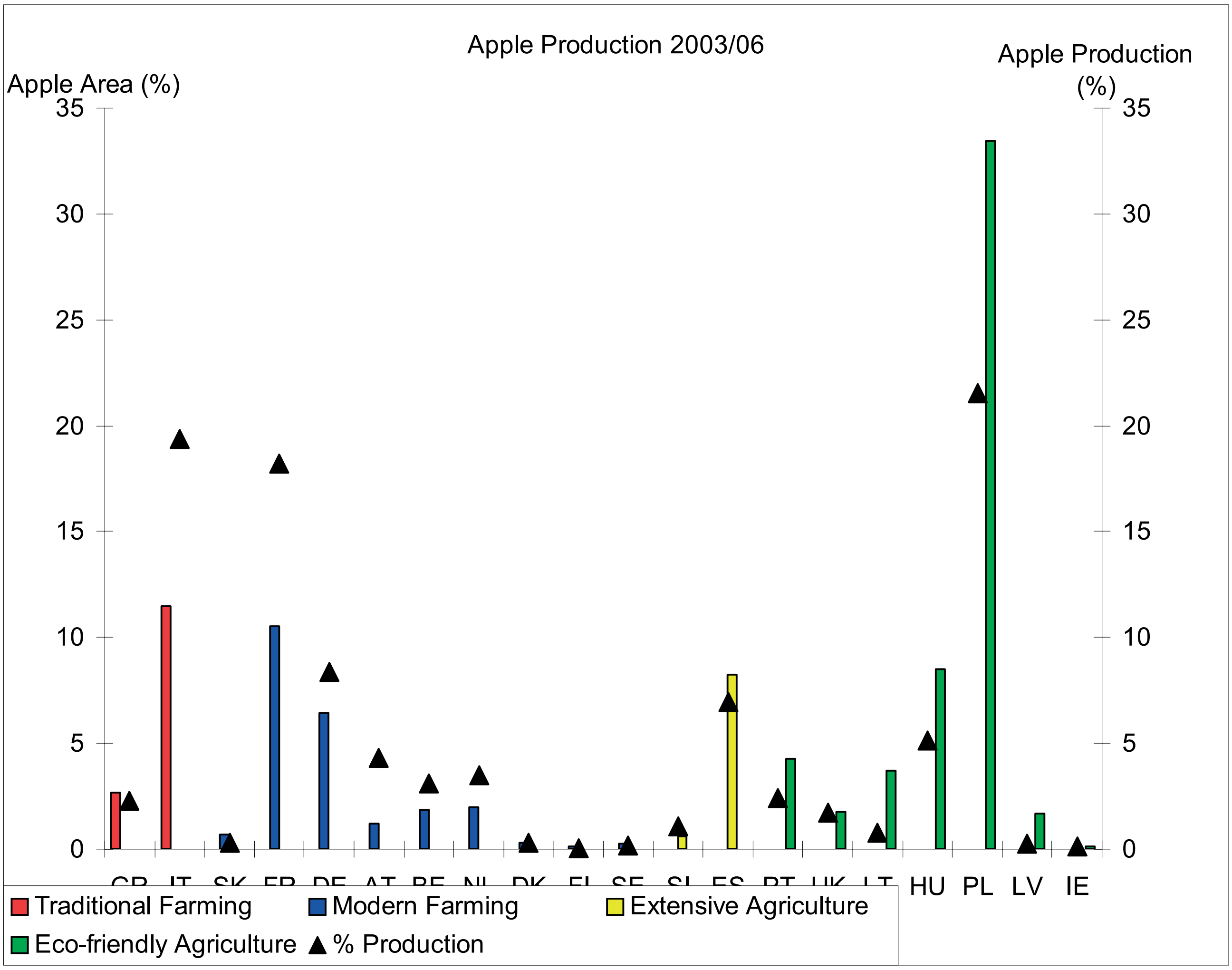
The production of apple in different countries of the EU between 2003 and 2006 is grouped in four agricultural systems, which are depicted in the Figure 17. Systems characterised by high intensive use of pesticides are represented by the red (conventional farming) and blue (modern farming) columns, while the yellow and green columns symbolise the agricultural systems, under which the intensity in use of pesticides is low (extensive and eco-friendly agriculture).

In the Figure 17, the higher crop productivity that is achieved when implementing conventional and modern farming is noticeable. The spot representing the share in quantity produced in the EU, in most of the cases is separated from the red and blue columns. This situation and an apparent increase in the separation between the position of the spot and the edge of the columns that occurs simultaneously with the augment in area harvested (in other words, for the highest columns) could imply that improvements in crop productivity are influenced by augments in area cropped.

In percentage of area under production in the EU, the modern farming and the eco-friendly agriculture are the most important agricultural system. Probably, this situation is a response to the increased demand for products that are produced with environmentally sound techniques (organic market), to the establishment of tighter rules and higher quality standards (e.g. set of minimum pesticide residues level) or the institutional promotion of sustainable methods of production (e.g. environmental payments).

The productivity attained through implementation of an extensive agriculture system can be only comparable (in absolute terms) with the crop output obtained under a modern farming scheme, if the area harvested is enlarged. That means that for a similar area under production, the outputs corresponding to extensive agriculture are lower and at contrary similar percentages of quantity produced are grown in smaller area under modern farming.

Figure 17. Agricultural systems used to produce apple in the EU between 2003 and 2006

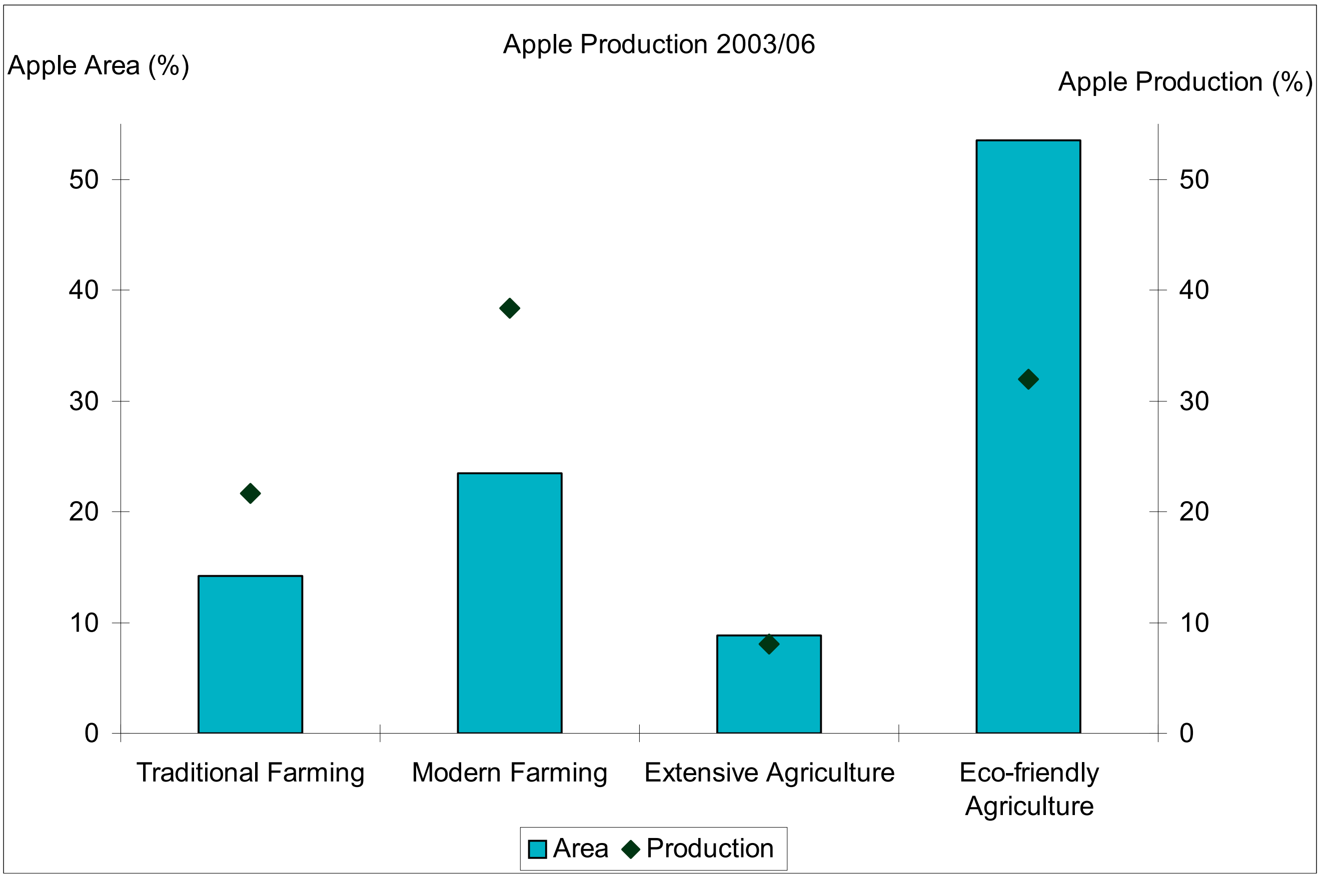


Data source: FAO

In the Figure 18, the cropping area and the crop production for each agricultural system implemented in apple growing in the EU between 2003 and 2006 are represented.

Agricultural systems characterised by high innovation in pesticide use have great importance in the production of apple in the EU, the highest percentages of production are attained under modern farming (38.4%) and eco-friendly agriculture (32%) and also the largest cropping areas in use are under these schemes of production (eco-friendly agriculture with 53.55 and modern farming with 23.4%). The productivity of traditional and modern farming (under which intensity in pesticide use is high) is higher than the productivity of extensive and eco-friendly agriculture (under which intensity in pesticide use is low).

Figure 18. Corresponding areas and productions of apple among agricultural systems



Data source: FAO

5. Conclusions

Being aware of the fact that the quantities of pesticides required in agricultural production depend on diverse factors such as natural conditions (e.g. weather, soil properties, pest pressures, etc.), production strategies and crop protection techniques, there is a common interest of the society to reduce the reliance on pesticide use. Consequently, the proposed classification of agricultural systems based on use of inputs is appropriate (more than a farm management strategies classification) to address crop protection strategies that rely less on use of pesticides.

An evolution in crop production from traditional farming to eco-friendly agriculture can be followed with the system of classification proposed. The two indicators of pesticide use are complementary. Intensity is equal to the quantities applied, while innovation encloses the properties and characteristics of the products applied. With this explorative analysis it is aimed not only to evaluate the current state of crop protection strategies, but also to contrast the strategies that are applied in different European countries. With that purpose it is important to remark that the information utilized is comparable.

The obtained classification indicates in which countries similar crop protection strategies are currently implemented. The objective of the classification is not to make an environmental analysis. For that purpose the criteria of evaluation would be limited, specially in the case of pesticide use innovation, because the estimation of potential hazards or effects have been mostly performed under standard conditions and for specific concentrations of AS. Additionally, other important factors that influence the effects of AS on the environment such

as soil properties and temperature, drainage, weather, application method, time and frequency were not taken into account.

From the techniques that were tested to impute missing data and the evaluation of different formats to aggregate variables towards assessing normative aspects and potential hazardousness, it is possible to say that in each case a variation was found in respect to a standard classification. From the results of the sensitivity analysis it is possible to say that the classification has a high stability and in only one case was extremely low and equal to 68.2%, which does not constitute a limitation to proceed with further analysis.

From the effects on the European averages (i.e. breakpoints of high and low pesticide use innovation levels) it is possible to conclude that the inclusion of variables to assess potential hazardousness has a positive influence in the final score. Dissimilarly, the inclusion of variables to evaluate normative aspects related to the products applied in the production of cereals and fruit trees has a negative influence in the European averages.

It is important to precise that the following conclusions are related to the classification of agricultural systems obtained when considering six variables to assess pesticide use innovation (i.e. authorisation status, hazardousness for human health, toxicity for beneficial organisms, toxicity for natural species, potential to pollute groundwater, and recommendations of use under IP) without imputation of missing data and assuming weighting factors (for the six variables) according with the results of the EOS.

For both productions of cereals and fruit trees we have found that the use of pesticides at high intensity levels is associated with higher crop productivity, as well there is evidences that in traditional and modern farming, the productivity is boosted with increments of the area under production. This fact can suggest some type of specialisation in the production. Similarly, the results confirm that crop yields associated to agricultural systems characterised by low pesticide intensity might be comparable in absolute quantities to those yields obtained under other systems, if the area under production is augmented.

An evolution in production of cereals in Europe might be supported with the facts that the indicator for pesticide use innovation has a value higher than the score obtained for the other crop group analysed and its value is significantly higher than the median of the transformation scale applied to assess this indicator, in addition, the allocation of only one country within the traditional farming systems reinforce this conclusion. The modern farming (characterised by high intensity level of pesticide use) is the most important agricultural system in terms of productivity, whereas the eco-friendly agriculture covers the largest area under production.

From the classification of agricultural systems that are currently implemented in production of fruit trees in Europe, it is possible to conclude that the evolution in crop protection is focused on use of pesticide products that contain less potential hazardousness, as the modern farming and the eco-friendly agriculture are the most important systems in terms of area under production, crop production and number of countries included.

Section B. Economic Sustainability of Plant Protection Strategies

6. Problem Setting

Sustainability brings together three complementary dimensions: society, environment and economy. Consequently, the objective pursued with sustainable farming practices is to meet food requirements with a production attained in a form that is harmless to humans and the environment to the extent that is technically and economically feasible (Madden and Dobbs, 1990). Technical aspects of agricultural systems and crop protection strategies may be improved by making the best possible use of the resources of production (land, labour and capital), while economic feasibility is related an agricultural production that is profitable.

Evaluations of the economic effects, which are associated to particular agricultural practices and specific crop protection strategies, should cover two aspects, first whether farmers are likely to better-off and second the consequences on the market-level (e.g. changes in macroeconomic variables such as market prices, farming areas, trade competitiveness, employment, incomes, etc.) (Madden and Dobbs, 1990). In this section B, the profitability of different agricultural systems, which are described in section A at farm level are carried out, while evaluations at macroeconomic level are planned for the third phase of ENDURE, when policy recommendations to improve adoption of sustainable crop protection strategies will be concluded and evaluated.

At farm level, the profitability is an important incentive in decisions about adopting farming systems or technology (see Dobbs and Foster, 1972). To obtain an accurate assessment of the profitability, the production plan of the whole farm should be taken into account. For that, management, labour and capital requirements and the complex interaction among crops, livestock enterprises, soils and populations of pests and their natural enemies should be well documented and measured. In other words, the influences of particular input on achieving crop yields and generating monetary returns should not be individually analysed, but simultaneously considered with other factors that exert any influence in crop production, for instances, production factors (land, labour, capital), management strategies (farmers' knowledge and decisions) and natural conditions (temperature, humidity, precipitation). In practice, such evaluations are not only time and cost demanding, but also require big efforts of a multidisciplinary research team. For that reason, the economic implications of performing specific agricultural practices are alternatively assessed by evaluating changes in income on individual farms based on analysis of costs and returns associated with a specific farm activity (e.g. crop protection). These calculations may be sufficient when making certain agricultural decisions (see Kay, 1986).

Furthermore, empirical economic analysis of crop protection techniques might be classified in two types of assessments: evaluations of economic effects when performing different agricultural production systems (e.g. Fernandez-Cornejo, 1998) and estimation of economic consequences generated when adopting different pesticide use reduction strategies (e.g. Orum et al., 2003). These economic consequences or effects at farm level are associated with variations in crop yield and gross margin.

Apparently, results derived from these evaluations are useful to identify strategies, under which crop yields and farm returns might be maximised, while using less quantity of inputs. Consequently, it could be possible to recommend reductions in pesticide use in a determined percentage. However, there are some facts that should be also taken into account. For instances the objective of crop protection to reduce crop losses, instead to increase productivity. Crop protection does not only rely on the use of pesticides, but also on use of non-chemical means (see Lichtenberg and Zilbermann, 1986). The maximum farm profit does not necessarily correspond to the highest level of crop protection, because there is a point beyond which crop protection costs

are higher than the cost associated with crop losses generated by crop pests and diseases (see Zadocks and Schein, 1979). Therefore, conclusions that there is a relation between crop yields and the specific amount of pesticides can not be drawn.

Due to the fact that data to assess all the aspects related to crop production in all the regions of the EU are not available, the profitability of different crop protection strategies related to the previously classified agricultural systems (in Section A) is analysed. Therefore, in the following Section B, costs of plant protection products and revenues for the agricultural systems are evaluated and compared.

7. Methodology

The economic viability of the different agricultural systems in the different countries of the EU is evaluated by estimating the proportion of crop protection costs in relation to total production costs and the revenues of crop production. For that, the average values of these two indicators corresponding to the four previously defined agricultural systems (in the Section A) are computed (and weighted with the harvested area) and compared.

7.1. Indicators

7.1.1. Proportion of crop protection costs in relation to total costs

This indicator represents the share of expenditures of crop protection products within the total production costs and is expressed in terms of percentage (%). Costs of crop protection products include value of pesticides, other products and equipments used for insect, fungus or weed control like traps and anti-hail shells. For total production costs all expenditures associated with farm operations (sowing, fertilisation, crop protection, irrigation, drying and storage) implemented in crop growing, labour and machinery requirements (wages, fuel, etc.) are taken into account.

When implementing a particular strategy of crop protection, production costs are not only affected by decisions on pesticide use (type, quantity and application technique), but also by changes in other farm management activities. For example the introduction of genetically modified varieties is connected with novel operating costs such as the planting of refuges of non-genetically modified plants may be linked (Gomez-Barbero and Rodriguez-Cerezo, 2006). Similarly, in the organic production of apples, higher input of human labour and costs of special activities like fallow land were identified (Brzozowski, 2004).

7.1.2. Revenues (Gross Return)

This value represents the total income that a farmer obtains in the case that the whole crop production is sold. The gross return is calculated by multiplying the crop yield (in t/ha) with the product prices paid to producers (in euro/ha) and is expressed in monetary terms per unit of harvested area (euro/ha). The output price is associated with the quality and characteristics of the crop output, for instances, the prices paid for organic apples are often higher than those prices paid for apples obtained under for conventional production (Brzozowski, 2004).

7.2. Database

7.2.1. Data and Sources

For the economic evaluation, data for the selected crops is taken from two sources. In the statistical database of the Food and Agriculture Organisation of the United Nations (FAO), crop yield, harvested areas and producer prices for wheat and apple productions are available. The Common Agricultural Policy Regional Impact (CAPRI[2]) modelling system supplies crop production and crop protection costs, crop yield, crop area and output price for soft wheat and the combined production of apple, pear and peach.

Crop protection costs include plant protection products, traps and baits, bird scarers, anti-hail shells, frost protection, etc. Crop production costs are expenditures for seeds and seedlings, fertilisers, crop protection products and others (soil analysis, purchasing of standing crops, renting crop land for a period of less than one year, purchase of crop products, cost incurred in the market preparation, storage, marketing of crops, etc) (FADN, 2008).

Average costs and prices associated with production of wheat and apple between 2000 and 2002 in different countries of the EU are listed in the Tables 23 and 24, respectively.

Table 23. Average prices and costs in wheat production between 2000 and2002

Crop	Wheat					
	Price	Yield	Area	Crop protection costs	Total crop production cost	Area
	euro/t	T/ha	1000 ha	Euro/ha	Euro/ha	1000 ha
AT	104.9	4.89	290.1	35.0	664.3	269.0
BE	105.8	8.08	198.9	150.6	887.2	204.6
CZ	106.9	4.54	914.2	40.4	401.5	813.1
DK	114.1	7.29	612.7	98.6	1082.3	613.9
EE	92.8	2.21	64.7	3.4	176.8	63.8
FI	132.7	3.41	156.2	34.5	670.9	170.1
FR	102.1	7.06	5081.7	133.3	804.0	4625.3
DE	109.1	7.36	2960.3	179.8	887.7	2951.9
GR	139.0	2.52	867.7	20.5	312.9	141.1
HU	96.5	3.81	1113.5	15.3	317.4	1146.3
IE	105.7	8.99	88.5	102.4	963.7	96.1
IT	169.5	3.05	2342.6	5.2	236.7	628.0
LV	105.5	2.93	159.5	7.9	287.9	164.3
LT	115.0	3.34	352.6	18.0	356.3	339.3
LU	130.1	5.68	10.9	103.8	699.8	10.8
NL	105.3	8.04	132.2	178.2	1141.3	129.4
PL	125.8	3.54	2558.8	14.5	340.7	2536.9
PT	117.3	1.40	213.5	6.7	131.1	40.8
SK	101.8	3.73	418.8	38.9	466.9	381.3
SI	139.4	4.58	37.8	36.8	499.2	36.1
ES	136.6	2.74	2312.2	20.7	249.0	1359.9
SE	110.8	6.00	380.1	9.5	1039.8	382.7
UK	121.3	7.70	1905.7	182.1	1065.9	1818.9
Source	FAO	FAO	FAO	CAPRI	CAPRI	CAPRI

[2] www.ilr1.uni-bonn.de/agpo/rsrch/capri/capri_e.htm

Table 24. Average prices and costs in apple production between 2000 and 2002

Crop	Apple					
	Price	Yield	Area	Crop protection costs	Total crop production cost	Area
	euro/t	T/ha	1000 ha	euro/ha	euro/ha	1000 ha
AT	307.5	77.11	6.0	379.0	9158.3	6.4
BE	294.3	46.70	8.8	789.2	6058.9	16.9
DK	524.5	12.71	1.7	399.9	3185.3	2.0
FI	1013.2	6.01	0.5	180.5	1919.8	0.6
FR	319.5	34.78	67.1	662.8	5609.3	85.0
DE	366.7	29.79	71.0	859.4	8722.2	35.1
GR	449.8	19.60	14.4	508.2	2639.6	60.4
HU	57.6	15.14	42.5	106.2	804.4	54.6
IE	361.8	23.00	0.7	303.4	2111.4	0.3
IT	391.4	36.24	61.9	111.9	1589.1	176.5
LV	70.9	4.97	8.2	19.3	306.2	8.9
LT	41.7	3.75	29.0	13.6	161.9	28.3
LU	578.3	8.68	1.1	948.1	7262.9	1.9
NL	326.3	34.13	11.9	689.1	7479.6	17.3
PL	59.5	12.09	166.7	154.6	1266.3	185.5
PT	529.7	12.38	21.3	169.9	2974.8	40.9
SK	271.0	16.61	3.9	353.5	3328.1	4.7
SI	312.8	36.86	3.2	325.2	2870.5	4.1
ES	302.5	18.15	44.8	300.0	1843.3	147.2
SE	450.8	14.31	1.4	606.1	4072.9	1.6
UK	686.6	17.73	11.3	648.7	3900.2	18.9
Source	FAO	FAO	FAO	CAPRI	CAPRI	CAPRI

The prices are called producer price in the FAO database. Harvested areas (from FAO source) are employed to calculate average weighted revenues for each agricultural system (according with the classification obtained in the Section A). Similarly, the relative crop protection costs for each agricultural system are corrected (weighted) with the crop areas (from CAPRI source). Finally, it is important to mention that the producer prices in the FAO database are expressed in US dollars; therefore, annual exchange rates US dollar/Euro were taken from the statistical data warehouse of the European Central Bank.

7.2.2. Data Limitations – Quality of the Information

Data obtained from FAO statistical databases correspond to average ciphers. In consequence, differences of prices according with quality of the product or production labels (e.g. organic, good agricultural practices, etc.) are not available. It is also obvious that the agricultural production is not carried out at the same intensity level within one country, but the data format does not allow to make any difference.

Although, the CAPRI modelling system presents data at regional level, only a national average for the output price are presented for each country.

CAPRI data is based on three sources:

1. Econometric estimations based on single farm data from the European Accountancy Data Network of the EU (FADN) (for which a sample corresponding to about 90% of the total utilised agricultural area in Europe is examined).
2. Engineering information.
3. Standard gross margins.

Information taken from the CAPRI modelling system corresponds to the average values of crop production between 2000 and 2002. For that reason the data extracted from FAO statistical database correspond to the same period of time.

7.2.3. Data Coverage

Both database, FAO and CAPRI modelling system, contain the required information at country level to calculate relative costs of crop protection products and revenues of crop production for all European countries included in the classification of agricultural systems (in the Section A).

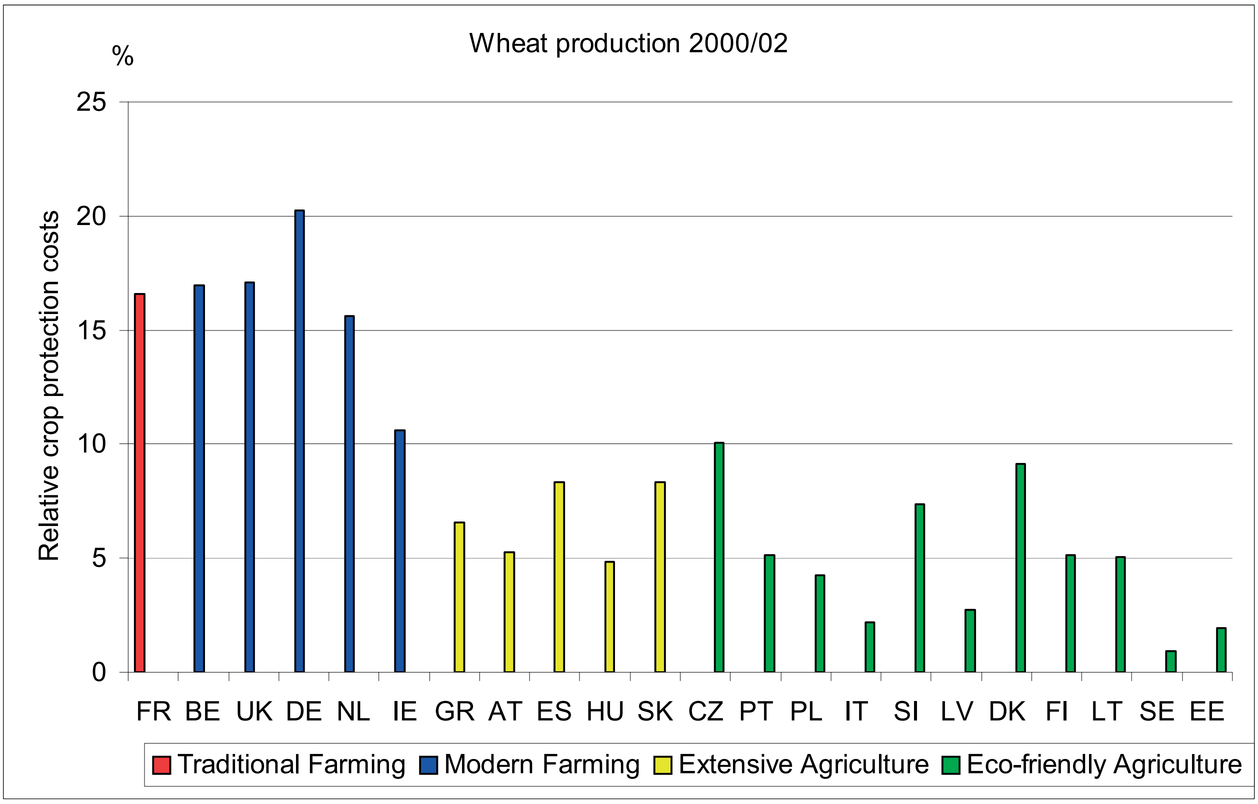
The calculation of the net farm income (which is calculated by summing up the revenues and the premium payments and subtracting crop production costs) is limited because the CAPRI modelling system only provides information on the premium payments to producers of wheat and apple in fifteen countries of the EU.

7.3. Calculation of Economic Indicators on National Level

7.3.1. Relative Crop Protection Costs

7.3.1.1. Wheat Production

Figure 19. Relative crop protection costs in wheat production between 2000 and 2002



Data source: CAPRI

In the Figure 19, averages values of the proportion of costs of crop protection products in relation to total production costs for soft wheat production in different European countries between 2000

and 2002 are illustrated. In the Figure 1, production under traditional and modern farming systems is represented by the red and blue columns, while the yellow and green columns correspond to extensive and eco-friendly agricultural productions.

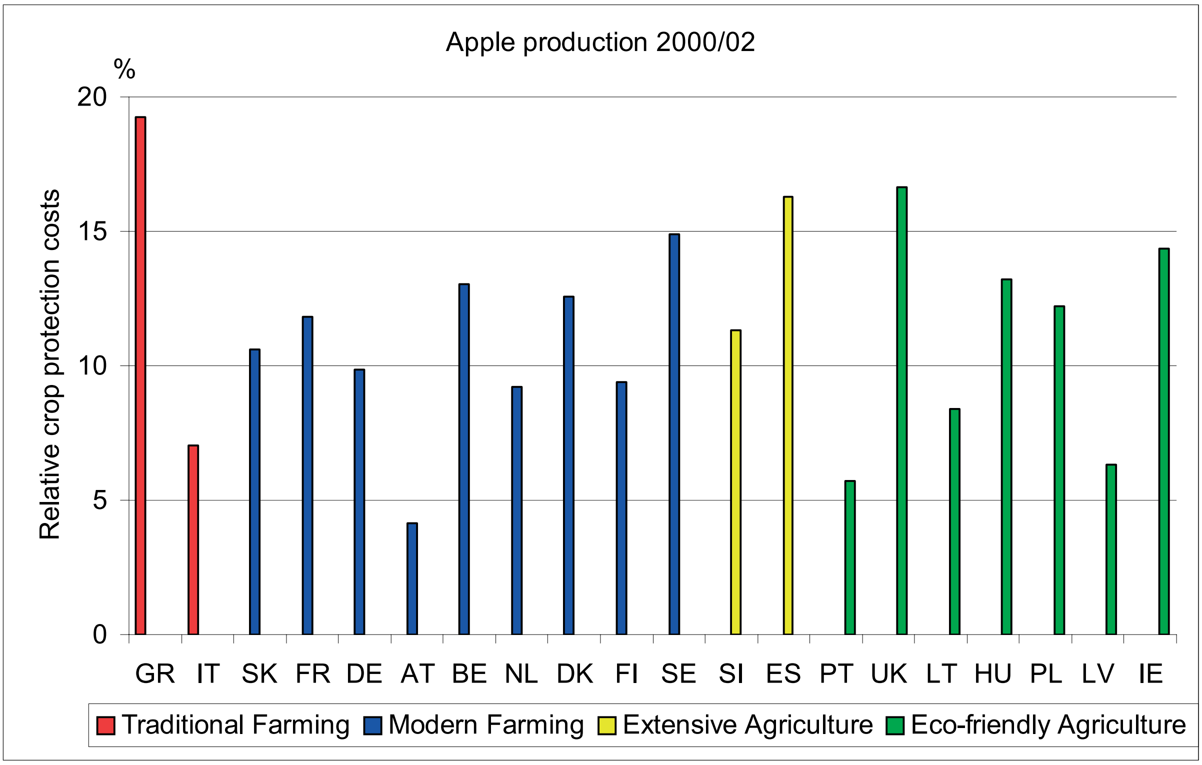
In wheat production, the EU countries with the highest relative costs of crop protection are classified within the agricultural systems characterised by the use of pesticides at high intensity levels, traditional farming (FR with 16.58%) and modern farming (DE with 20.25%, UK with17.08%, BE with 16.98%, and NL with 15.61%). Contrarily, the countries with the lowest relative costs of crop protection (SE with 0.92%, EE with 1.95%, IT with 2.20% and LV with 2.75%) are found within the eco-friendly agricultural scheme, under which the level of pesticide use intensity is low.

7.3.1.2. Apple Production

For apple growing in the EU between 2000 and 2002, the average percentages of crop protection costs in relation to the total expenditures are depicted in the Figure 20, where red columns symbolise production under traditional farming, while modern farming is represented by the blue columns. The yellow columns stand for extensive agriculture and eco-friendly agriculture corresponds to the green columns.

The lowest relative costs of crop protection were attained under schemes of production characterised by high levels of pesticide use innovation, modern farming (AT with 4.14%) and eco-friendly agriculture (PT with 5.71% and LV with 6.32%), while the countries with the highest relative costs of crop protection are present in the four agricultural systems, traditional farming (GR with 19.25%), eco-friendly agriculture (UK with 16.63%), extensive agriculture (ES with 16.27% and modern farming (SE with 14.88%).

Figure 20. Relative crop protection costs in apple production between 2000 and 2002



Data Source: CAPRI

7.3.2. Revenues

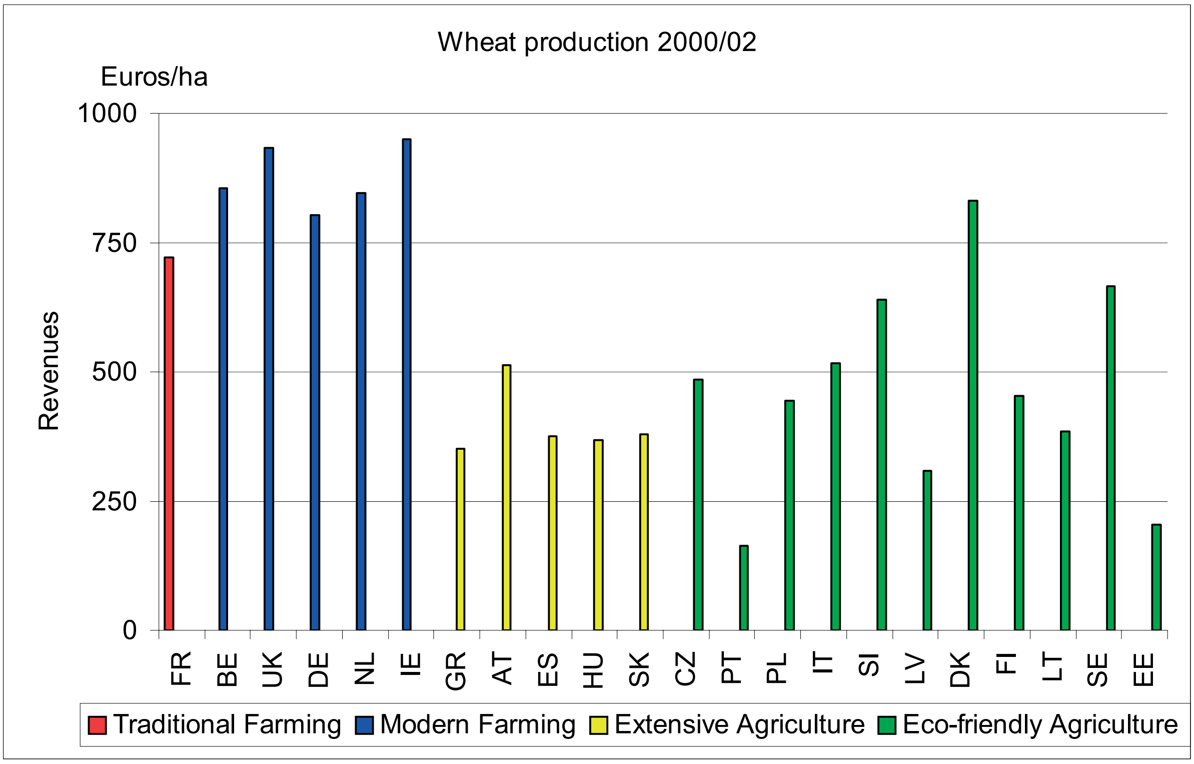
7.3.2.1. Wheat Production

In the Figure 21, average revenues (in Euro/ha) obtained from wheat production in different countries of the EU between 2000 and 2002 are illustrated. In the Figure 3, traditional and modern farming are represented by the red and the blue blocks, while the yellow and green blocks stand for extensive and eco-friendly agriculture.

In the Figure 21 is appreciable that under traditional and modern farming systems the highest revenues in wheat production are obtained. It is remarkable that as an exemption, the revenues attained in DK under an eco-friendly agriculture are very high (831.77 euros/ha). The highest revenues in production of wheat were obtained in IE (949.9 euros/ha), UK (934.01 euros/ha), BE (854.91 euros/ha), NL (846.54 euros/ha) and DE (802.7 euros/ha).

Dissimilarly, in PT (164.07 euros/ha) and EE (205.04 euros/ha), the lowest revenues in wheat production were attained, both countries belong to the agricultural system characterised by low levels of pesticide use intensity and innovation.

Figure 21. Revenues obtained in wheat production



Data source: FAO

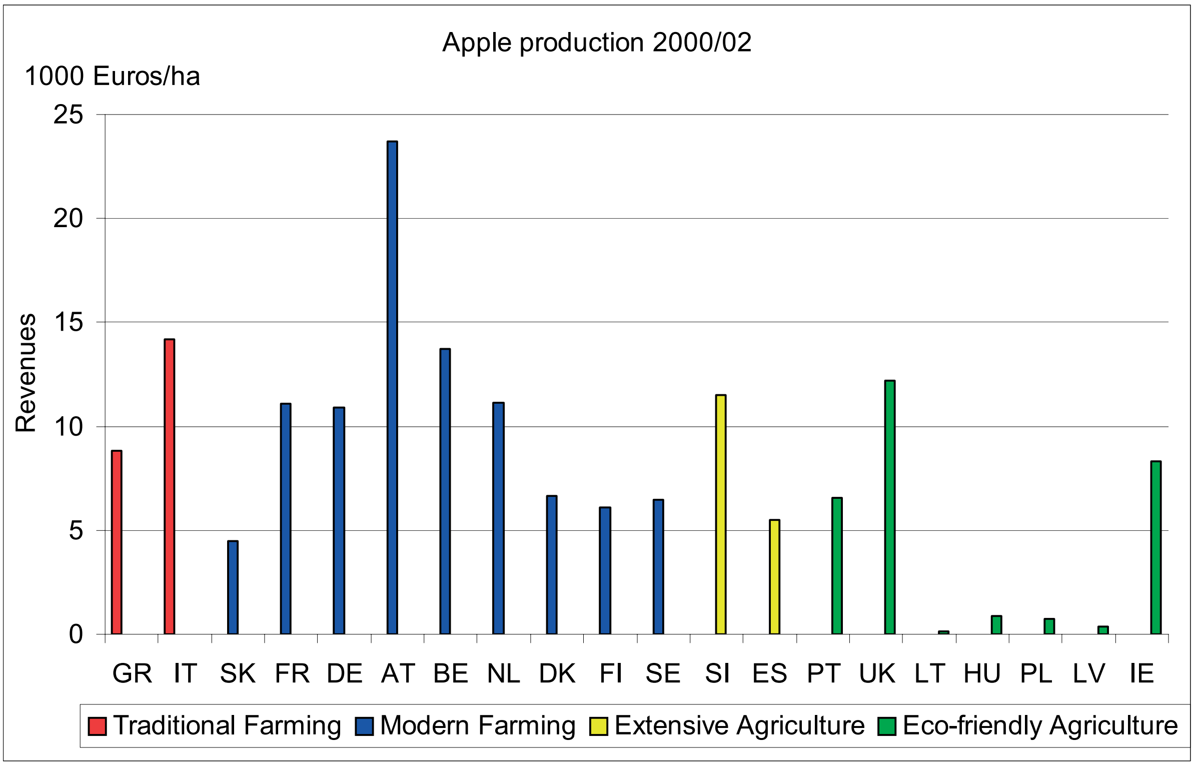
7.3.2.2. Apple Production

Revenues (in 1000 euros/ha) generated from apple production in different countries of the EU between 2000 and 2002 are shown in the Figure 22, where traditional farming corresponds to the red blocks, blue blocks symbolise modern farming, yellow blocks stand for extensive agriculture and eco-friendly agriculture is represented by the green blocks.

In the Figure 22 it is noticeable that the revenues obtained in AT are extremely high (23714 euros/ha) and also that countries with the highest revenues are distributed in the four agricultural systems, traditional farming (IT 14184 euros/ha), modern farming (BE 13741 euros/ha), eco-friendly agriculture (UK 12177 euros/ha) and extensive agriculture (SI 11528 euros/ha). While, countries with the lowest revenues in apple production are classified within the extensive and eco-

friendly agriculture scheme (LT with 156 euros/ha, LV with 352 euros/ha, PL with 719 euros/ha and HU with 871 euros/ha), under which the pesticide use is low in terms of intensity and innovation

Figure 22. Revenues obtained in apple production



Data source: FAO

8. Economic Evaluation of Four Agricultural Systems

The profitability of crop protection strategies associated to different agricultural systems depends on changes or particular values of crop yields, costs of pests, insects and weed controls, variable production cost (e.g. seed prices) and product prices (Gomez-Barbero and Rodriguez-Cerezo, 2006).

In this explorative phase of the analysis of economic driving forces in crop protection and according with the availability of information, the economic evaluation of crop protection strategies corresponding to four defined agricultural systems is carried out by estimating average values of relative costs of crop protection (in % of total production cost) and crop revenues (in euros/ha).

It is also important to note that for each agricultural system, average values are weighted with the harvested area in each country. This estimation of weighted values aims to give more importance within the average values to those economic indicators resultant from larger aggregated productions at country level.

Finally, it is important to remind that the classification of the four agricultural systems is based on two dimensions of pesticide use, intensity and innovation. The four systems are: traditional farming (high-intensity and low-innovation in pesticide use), modern farming (high-intensity and high-innovation in pesticide use), extensive agriculture (low-intensity and low-innovation in pesticide use) and eco-friendly agriculture (low-intensity and high-innovation in pesticide use).

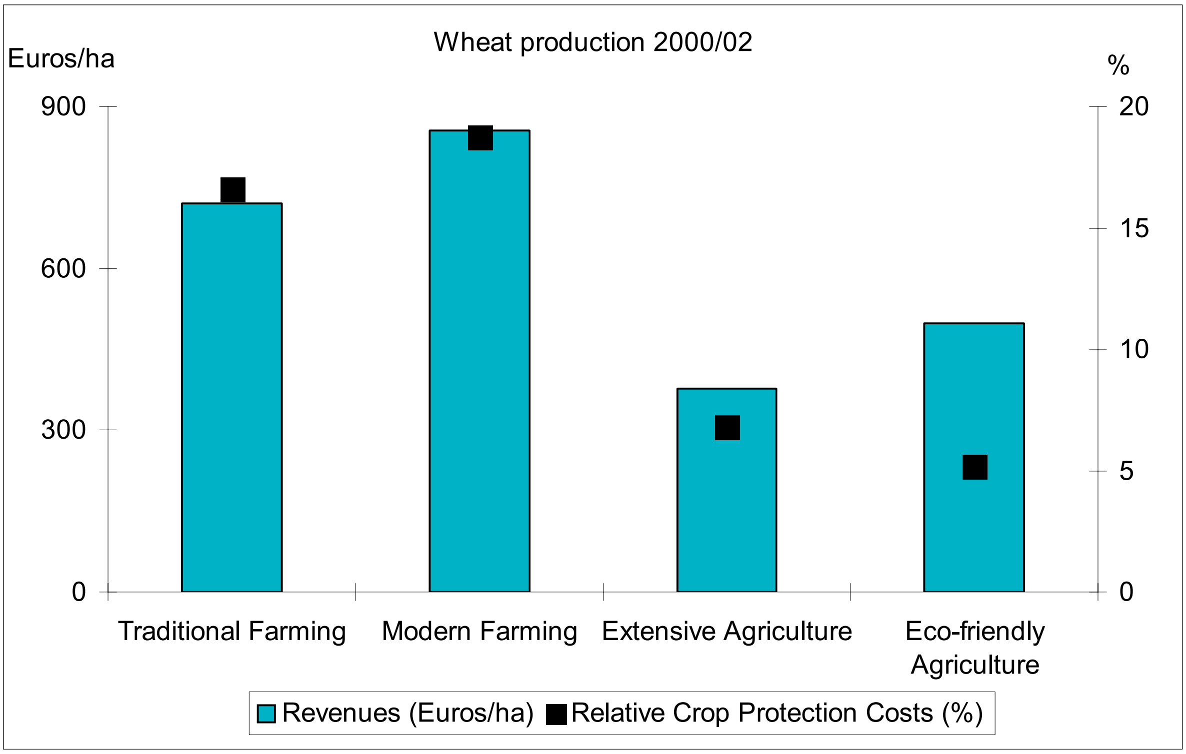
8.1. Wheat Production

In Figure 23, the relative costs of crop protection (in % of total production cost) and the revenues (in euros/ha) for wheat production in the EU between 2000 and 2002 are illustrated. It is observable that for the agricultural production characterised by high-intensity in pesticide use (i.e. traditional and modern farming), the highest relative costs of crop protection and the highest revenues are obtained.

In the Figure 23 is also noticeable that increments in revenues coincide with higher innovation in pesticide use for the wheat productions characterised by low pesticide use intensity (i.e. higher revenues are attained under eco-friendly agriculture than under extensive agriculture). Similar behaviour is also observable for wheat productions characterised by high pesticide use intensity (i.e. higher revenues are attained under modern farming than under traditional farming).

Furthermore, under schemes of production with low intensity in pesticide use, the costs of crop protection products are lower for the crop growing with high levels of pesticide use innovation (i.e. relative costs of crop protection products are higher in extensive agriculture than in eco-friendly agriculture).

Figure 23. Revenues and relative crop protection costs in wheat production



Data source: FAO (for revenues), CAPRI (for relative crop protection costs)

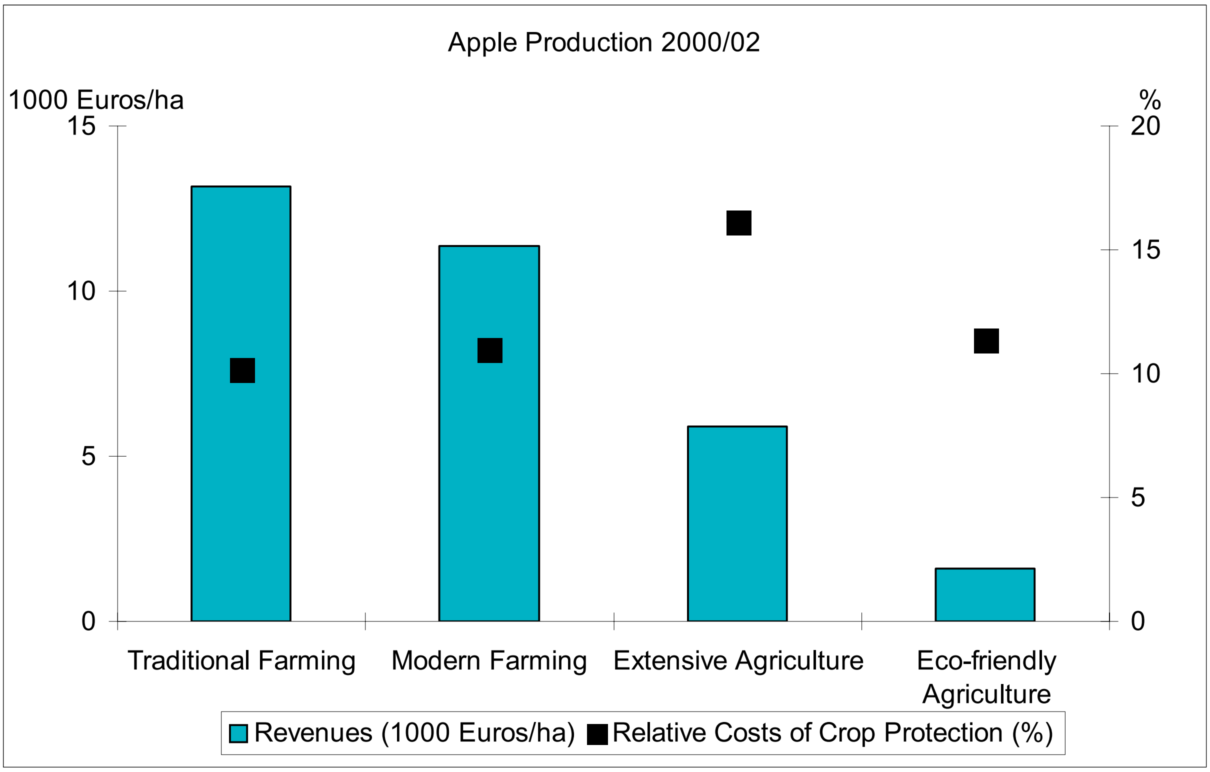
8.2. Apple Production

The relative costs of crop protection (in %) and the revenues (in 1000 euros/ha) for apple production between 2000 and 2002 in the EU are depicted in the Figure 24. The generation of higher revenues is associated with the use of pesticides at high-intensity levels (i.e. traditional and modern farming). While relative costs of crop protection are higher for agricultural production systems that are characterised by low-intensity in pesticide use (i.e. extensive and eco-friendly agriculture). In addition, lower crop revenues are obtained for agricultural systems that are

characterised by low innovation in pesticide use at both levels of pesticide use intensity (high-intensity and low-intensity).

The relative costs of crop protection associated to traditional farming (low innovation in pesticide use) are lower than those costs related to modern farming (high innovation in pesticide use). A contrary situation is observed for the agricultural systems characterised by low-intensity in pesticide use, it means that the relative costs of crop protection products are higher under a crop production scheme with low innovation in pesticide use (extensive agriculture) than for a scheme with high innovation in pesticide use (eco-friendly agriculture).

Figure 24. Revenues and costs of crop protection products in apple production



Data source: FAO (for apple), CAPRI (for apple-pear-peach)

9. Conclusion

For production of wheat and apple, there are three facts that coincide in this economical analysis:

- Higher revenues are obtained under production schemes characterised by high intensity in pesticide use (i.e. traditional and modern farming).

- For productions characterised by low intensity in pesticide use, the relative costs of crop protection products are lower, if the level of pesticide use innovation is high (i.e. lower relative costs of crop protection products under eco-friendly agriculture than under extensive agriculture).

- Expenditures in crop protection represent a larger percentage within the crop production costs in modern farming than in traditional farming.

Section C. Selection of Case Study Regions

10. Problem Setting

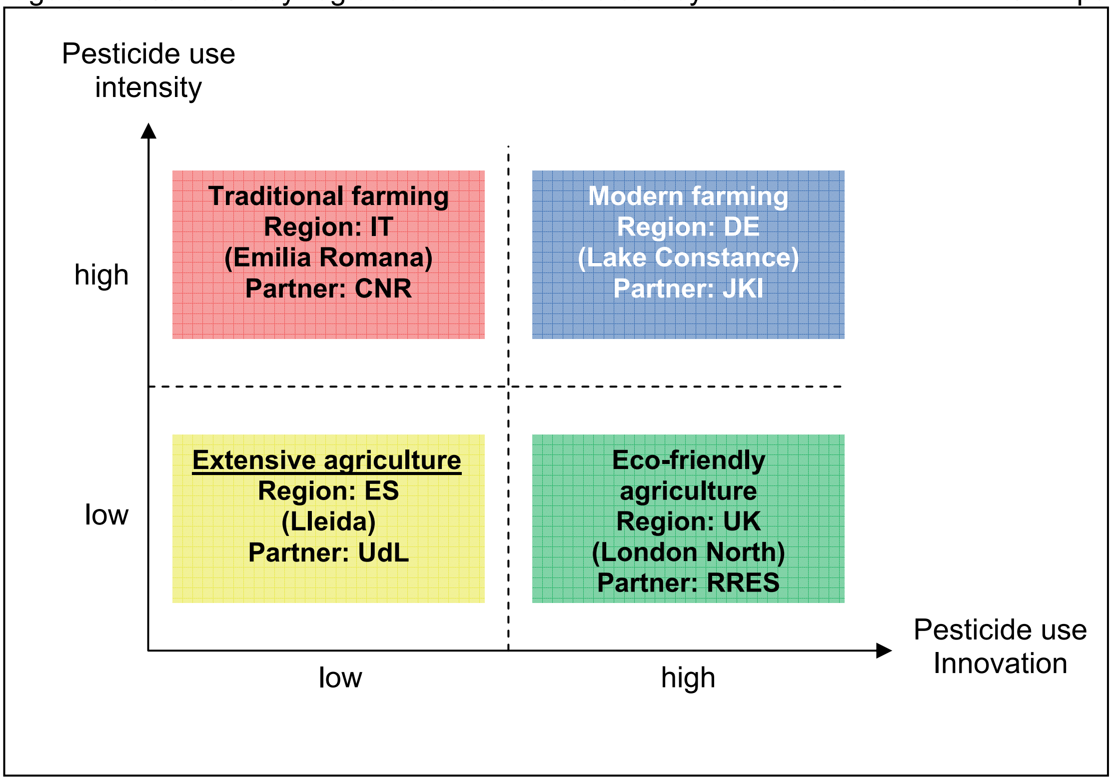
To identify sustainable management practices that might be adopted by farmers, it is necessary to understand social, ecologic and economic conditions around farmers. From the previous classification of agricultural systems (Section A) and the economic evaluation (section B), it is possible to recognize the currently trend in crop protection in Europe based on pesticide use. This evaluation represents the first step to achieve the objective of making policy recommendations to ensure the implementation of those crop protection strategies that are less reliable on the use of pesticides and that are still economically viable.

Therefore, for each of the 4 identified cropping systems, a case study region is selected. During the second phase of this research activity 3.2, a survey on farm level will be conducted, having the apple production as the case study crop.

11. Case Study Regions

In the Figure 25, the selected case study regions (country and region) for each agricultural system, as well as the ENDURE partner are shown. In these four regions, a survey on farm level will be conducted to obtain with high accuracy information about pesticide use, economic situation, farm management and crop protection strategies. The selection of the four case study regions depends on the availability of data (e.g. statistical databases) and the presence and potential collaboration of Endure partners.

Figure 25. Case Study regions selected for the survey on farm level and ENDURE partners



The Emilia Romana (Italy) region represents the traditional farming, while the Lake Constance (Germany) stands for the modern farming. The extensive agriculture is examined in Lleida (Spain) and the eco-friendly agriculture in the north of London (United Kingdom).

The ENDURE partners and potential collaborators for conducting the survey on farm level are: Consiglio Nazionale delle Ricerche (CNR) in Italy, Julius Kühn-Institut (JKI) in Germany, Universitat de Lleida (UdL) in Spain and Rothmasted Research (RRES) in the United Kingdom.

12. Required Information

Recognizing that crop protection strategies are not only influenced by crop production and management strategies, but also by environmental and natural conditions and public regulations (Radcliffe, 2002), a description of the predominant weather conditions (i.e. precipitation, temperature, humidity) and soil characteristics is required. It is also necessary to describe the institutional regulations by identifying pesticide policies that are functioning in each region of our study. The agricultural and environmental policy instruments that are related to pesticide use might be divided in three groups: regulatory instruments (e.g. regulation and authorisation of use of plant protection products directive), economic instruments (e.g. taxes on pesticide use) and persuasive instruments (e.g. education, extension and training programmes) (OECD, 1997).

Based on the survey on farm the following information will be collected:

1. Pesticide use
2. Economic data
3. Factors that influence pesticide use

12.1. Pesticide Use

On farm level, the information about pesticide use is asked by commercial product and quantity applied. But, the analysis of the information is conducted with applied quantities of active ingredients, as the application rate depends on the characteristics of the product, for instances for newer products, the doses can be low because the concentration of the active substances is high (see Hoyer and Kratz, 2001).

It is also important to remark that the pesticide doses that are actually applied may differ from the amounts that are recommended. For example, lower than recommended dosages of herbicides might be achieved, if mechanical weeding is implemented. Dissimilarly, fungicides and insecticides may be frequently overused with respect to recommended dosages, if they are sprayed as a preventive measure, which could be encouraged by their relative low costs when compared with herbicides (de Snoo, 2003).

In terms of pesticide use innovation, it is necessary to mention that increments in pesticide testing and registration requirements have negatively affected the introduction of new products but have encouraged the development of pesticides with fewer toxic side effects (Ollinger and Fernandez-Cornejo, 1998). Consequently, pesticide products containing new active ingredients and formulations are expected to be more innovative.

12.2. Economic Data

To assess how viable the crop production in the different regions is, it is necessary to consider the costs and the revenues associated. The revenues are calculated as the product of the crop yield and the price obtained for the crop produced, while the costs include the expenditures for field operations and requirements of energy and machinery. Reductions in the use of chemical pesticides normally are followed by higher labour requirements, especially for weed control (Struik and Kropff, 2003).

On the other hand, high intensity in the use of pesticide may contribute to attain high yields, but the revenues could be offset by increments in crop protection costs. However, the economic returns could be favourable as a result of higher output prices and payment of agro-environmental subsidies (Brzozowski, 2004). Then, the competitiveness in crop production in one region would rely on lower labour costs (idem).

12.3. Economic driving forces of pesticide use

For this analysis, farmers' decisions to adopt innovations (e.g. crop protection strategies that are less reliable in the use of pesticides) could be defined as a function of farmer's characteristics, management practices, farm structure and institutional issues. McNamara et al., 1991, applied this scheme to evaluate the adoption of integrated pest management strategies.

12.3.1. Farmer characteristics

In a Portuguese study, that aimed to identify the influence of household characteristics on the adoption of agrarian innovations the conclusion was drawn up that younger farmers with advanced education level and more experience in agricultural production are those, who presumably would adopt novel agricultural strategies and techniques (Unwin, 1987). However, these results should not be generalised. Different researches on adoption of soil conservation technologies have shown that the implementation of innovations is related to farmer's awareness of the problems and potential solutions and dissemination of the information. In addition the education level of the farmers, specific or general, commonly is significantly associated with the acceptance of new agricultural practices. But conclusions about driving forces such as age and farming experience with the adoption of innovations can not be drawn up, because these factors have been qualified in different studies either as having positive or negative correlations (FAO, 2001).

12.3.2. Farm Structure

In addition to the farm size (Rahman, 2003), another important factor, that influence the use of pesticides, is the expansion in crop production (OECD, 1997).

As apple orchards are normally a monoculture production, they have higher pest pressure and consequently they demand more external inputs. In addition the productivity of the apple orchards is related to its age (Jungbluth, 1999).

12.3.3. Farm Management Practices

12.3.3.1. Farmer's decision to use pesticides

The decision of the farmers to use agrochemical products is the result of their evaluation of product effectiveness, product price advantage over other alternatives, environmental risk awareness and simplicity of use (de Snoo, 2003). However, farmers are unlikely to switch to new improved pesticides when older, cheaper or off patent products are still available. Thus, new pesticides only realise advantages in the market if they can compete effectively on price with the existing products (Tait, 2001). In an analysis of the availability of the pesticide products in the Dutch market, it was concluded that farmers apparently stick in using products that they know well (see de Jong et. al, 1999). Other reasons associated with the decision to apply pesticides are related to their simplicity of application and the rapid action in killing pests (see Pimentel et al., 1951).

Farmer preferences to apply at higher dosages than recommended with the purpose of ensuring the achievement of an usually known level of crop protection or crop yield influence the quantity of pesticides that is applied (Falconer and Hodge, 2000). However, it is necessary to mention that the effectiveness of pesticide use should be related to changes in agricultural practices and the development of pest resistances. That could be supported with the fact that during five decades in the US the use of pesticides augmented while crop losses remained stable (Pimentel, 1997).

12.3.3.2. Use of non-chemical crop protection strategies

Within the concept of integrated plant protection, farm practices such as the use of local adapted resistant varieties, protection of beneficial organisms and elaboration of regional lists containing restricted and prohibited pesticides products according with their toxicity have gained increasing importance (Boller et al., 1999)

Crop losses might be minimised (and subsequently pesticide use could be reduced) by improving the monitoring systems and by adjusting crop production combined with better education and extension service (Orum et al., 2003). Similarly, pesticide use reductions are possible, if the technology available is used and also if the current inputs are economically utilised (see Zadocks and Schein, 1979).

12.3.4. Institutional issues

The effects of agricultural and environmental policy in farmers' decisions related to pesticide use intensity and innovation depends on the policy mechanism and on the farmers' responsiveness to these instruments. Farmers' responsiveness is associated with availability and acquisition of reliable information.

In the EU, the institutional efforts are oriented to minimise the hazards and risks to health and the environment derived from pesticide use by replacing the most dangerous pesticide products, encouraging low-input or pesticide-free farming and increasing the awareness of the society respect to the risks derived from pesticide use, as proposed in the 'Thematic Strategy on Sustainable Use of Pesticides' that was adopted in 1999 by the Agricultural Council.

Among the strategies implemented to achieve the objectives of this thematic strategy it is necessary to mention the implementation of pesticide use reduction policy, the promotion of alternative crop production strategies such as organic farming and the establishment of agricultural payments (OECD, 1997).

In addition the use of pesticides may be also influenced by consumer preferences such as diet preferences and aesthetic standards set on the market (Reitz et al., 1999).

Section D. Analysis of the effect of pesticide regulation on the development of crop protection products by agro-industry

13. Context, objective and related literature

This aim of this task is to analyse the impact of the regulation related to pesticide on the supply of new pesticide products since the beginning of the 90's. The major evolution to be mentioned is the directive 91/414. This directive established that market approval of each active ingredient is granted at the European level while the market approval of each pesticide product is granted by national authorities. This directive also strengthened the toxicology and eco-toxicology criteria that have to be met by existing and new active ingredients. It should be noted that a 10 years delay has been granted for all the active ingredients that were approved before this directive. The analysis of the impact of REACH is not in the scope of this analysis because this regulation is too recent (2007).

It is expected that the 91/414 directive should lead to the withdrawal of active ingredients and pesticides. However, this reduction is expected to be compensated, at least partly, by the introduction of new families of active ingredients and the corresponding pesticides. Two other phenomena may also affect the evolution of the supply. First, the exhaustion of the patent related to some active ingredient leads to new generic products. However this evolution does affect only the number of products and not the variety of products because the generic products are identical to the existing ones. Second, several mergers and acquisitions occur in this sector during the last two decades. Each time it occurs, the merging firms rationalise their product portfolio by eliminating the overlapping products and possibly introducing some new ones to explore new market opportunities. In summary, a first challenge of this research is to estimate the effect of the regulation on the supply of pesticides by controlling for the effect of other factors (new family of active ingredient, new generics, mergers and acquisition) that also affect this supply.

This analysis is applied to the French pesticide market. The pesticide market is highly fragmented. Market segments are defined with respect to the crop and the pest. The correspondence between market segments and products is complex: some products are commercialised on a rather wide range of market segments, while others correspond only to one more precise segment. A second challenge of this research is to analyse the impact of the regulation on the supply in each segment. It is generally acknowledged by experts that the regulation leads to critical situation in some small market segment with very limited ways to control for some pest (orphan crop issues).

Very few contributions have been made in the economic literature on the pesticide industry and more particularly for the subject considered here. Ollinger et *al.* (1998) analyse the impact of the evolution of FIFRA regulation in the US on the supply of new ingredient during the 70's and 80's. They show that a 10% increase in the regulation cost leads to a 20% decrease of the number of new active ingredients. They show also that, during these two decades, the number of active ingredients as been divided by 2 for large crops and by 3 or 4 for small crops (fruits and vegetables and cash crops representing less than 40.000 ha). Courbois (1998) compare the supply of pesticides in the US between 1991 and 1997, and show that the number of product increases for most of the crops and pesticide categories (herbicide, insecticide, fungicide). Two main arguments can explain the apparent contradiction between these two contributions: (i) the two periods studied are different, and (ii) the first analysis considers the supply of active ingredient while the second consider the supply of pesticide[3]. Our analysis complements these two previous works by looking at the European case and by exploring in more details the determinants of the evolution of the supply.

Data collection

This analysis is based on the French ephy database that covers all the pesticide products approved in France during the last decades[4]. This database covers both products that are still

[3] The introduction of generic pesticide is taken into account when considering the supply of pesticide but not for the supply of active ingredient.

[4] This database is in French and is freely available in the following web site :

approved and those that are no longer approved. For each product ephy provides a rich set of information: the composition of the product (active ingredient), the date where the market approval as been granted and (possibility) withdrawn, the firm that commercialises the product, the set of other pesticide products that are similar or identical (same active ingredients), the range of uses for which the product is approved, and the different precautions related to the toxicity of the product.
The database covers more than 18000 products. No restriction has been made with respect to the market segment (crop or pest) and the period during which the products are approved. About two thirds of these products are no longer approved while one third are still approved. The current ephy database has three main drawbacks that we have fixed (or we are currently fixing) by a complementary work. First, firms were identified by there name and not by a code so that problem of mistakes in the orthography and synonyms had to be fixed. Second, more than 2300 uses are defined in this database but they correspond to various hierarchical level. More precisely some uses may be considered as included in other one because they correspond to a more precise pest and/or a more precise type of crop[5]. An important standardisation work has been made in order to control for these various hierarchical levels[6]. Third, a synthesis of the information on the dates of approval and withdrawal has to be made for each product because this information was distributed in different fields. This last work is currently ongoing and the data concerning the approval dates are still incomplete. These additional works on the database were partly unexpected and this explains why we are only able to provide preliminary results for the time being.

14. First and preliminary results

We provide here some descriptive statistics of the database as preliminary results. 12000 products have been withdrawn and the figure 1 indicates the distribution of the withdrawal years. During the last 20 years 550 products has been withdrawn each year in average and the figure 1 indicates that the rhythm as been more erratic since 2000 but not different in average.
Most of the products enter into the insecticide, fungicide and herbicide categories (table 1). The cash crop, fruit trees and vegetables are the market segments with the highest number of products. The use of bactericides products for buildings and material is the fourth main market segments for the number of products. It should be observed that the total number of product from this table is much larger than 18000 because most of the products have several uses.
1500 different firms are identified in the database among which one third commercialise only one product, one third commercialise between 2 and 5 product and one third commercialise more than 6 product (table 3). 10% of these firms can be considered big players with more than 20 products. Bayer is the firm with the highest number of products (651). 80% of the products are commercialised by the 17% of the firms (i.e. those selling at least 10 products)

http://e-phy.agriculture.gouv.fr/
[5] For example, the use that corresponds to the control for a precise fungus problem on wheat is included in another use that corresponds to the control for fungus problems in cereals.
[6] The standardisation as been made on the basis of the "index phytosanitaire".

Figure 26. Number of pesticide withdrawal

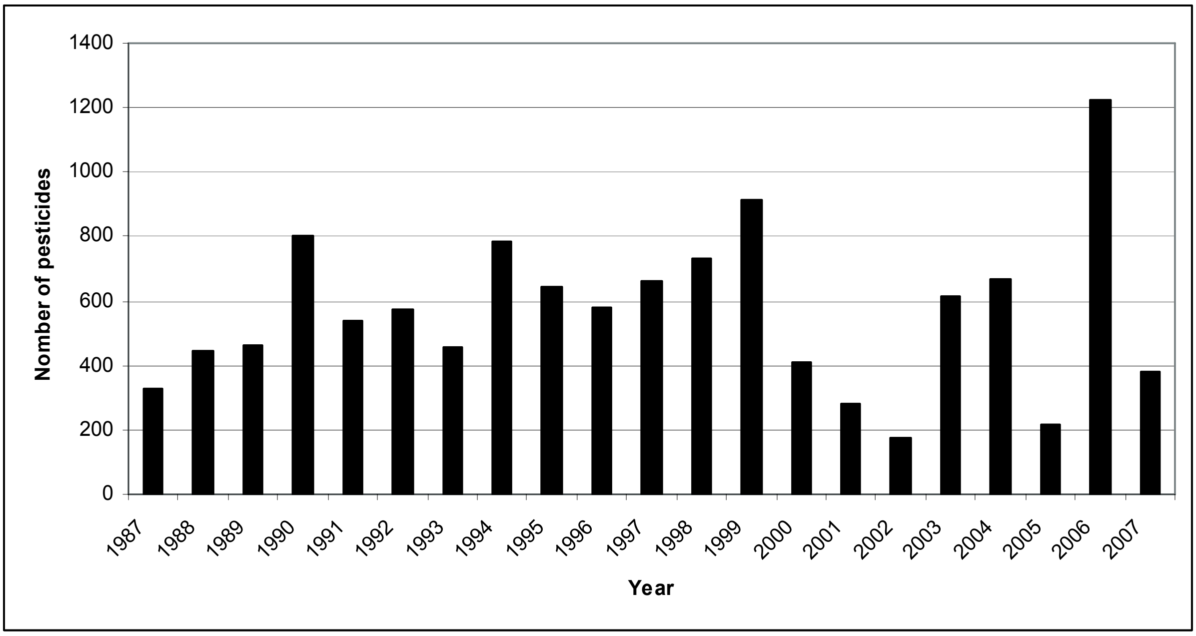


Table 25. Distribution of pesticide per type of crop and type of pest

Crop	Insect	Fungus	Weeds	Bacteria	Vertebrate	Divers	Virus	Growing subs.	Undefined	Total
Cash crops	9029	12154	8652		361	239		625	1	31061
Fruit trees	11884	4866	2355	485	1	91		168	3	19853
Vegetables	8936	7064	1625	208	7	128	2	33	10	18013
Buidings and material	867	3656		9661			706			14890
General treatment	1128	740	5729	52	3313	1091	14	76	42	12185
Vine growing	2490	3057	628			149		67		6391
Ornemental crops	1958	1416	1642	9	19	209		205	17	5475
Undefind			62	3086			809			3957
Forages	295	56	857			376		2	1	1587
Forest	206	72	617		42	24		2		963
Cultures diverses	385	204	206			56		41		892
Tropical crops	38	41	232			52		7		370

Table 26. Distribution of the number of firms per number of product commercialized

Number of products	1	2	3	4	5	6-10	11-20	21-100	101-650
Number of firms	564	248	137	87	65	180	104	124	36

15. Perspectives

We plan to carry on and finish this analysis during the next 18 months. We expect to release a working paper with a complete analysis of this dataset by the beginning of 2009. We plan to contact experts from the DIVE division of the AFSSA who is in charge of the approval process in France. The objective is to validate of our result with experts and to provide a better qualitative explanation of our results.
We plan also to prospect whether it will be possible to extend this analysis to other European countries. Our results will be presented in the ENDURE network and we will contact our foreign partner to draw up an inventory of the different databases of products approved in the different European countries. We will try to apply our analysis to other countries if rich enough database can easily be available without excessive additional work. If possible, this work will be made in collaboration with ENDURE partners.

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17. Annexes

17.1. Annex 1. Information used to assess pesticide use intensity

Table 1. Top 5 AS used in production of cereals in 2003 (in tons)

AS	Type	Chemical Class	AT	BE	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LV	NL	PL	PT	SE	SI	SK	UK
2,4-D	H	Phenoxy	**0.4**		**0.2**				**0.2**			**0.1**	**0.2**		**0.2**	**0.04**	**0.04**		**0.3**				**0.3**	
Carbendazim	F	Benzimidazole																					18	
Chlormequat	PGR	Physiological		**0.3**	**0.2**	**0.3**				**0.04**	**0.3**								**0.1**					**0.4**
Chlorothalonil	F	Aromatic												68										
Chlorotoluron	H	Urea																				21		
Dicamba	H	Benzoic-acid						5								12	2							
Dichlorprop	H	Phenoxy	38																					
Dichlorprop-P	H	Phenoxy								24			52								96			
Fenpropidin	F	Unclassified																				2		
Fenpropimorph	F	Morpholine					57							44				38						
Glyphosate	H	Organophosphorus			**0.2**	**0.2**	590		**0.2**	**0.3**	**0.2**	**0.1**	**0.1**	**1.0**	**0.2**	**0.2**	**0.2**	**1.5**	**0.1**	**0.1**	**0.6**	**0.1**	**0.1**	**0.5**
Imazamethabenz	H	Imidazolinone										14												
Isoproturon	H	Urea	32	313	144	3159			373		3502				40			255	1355	47	189	5		2576
Linuron	H	Urea															6							
MCPA	H	Phenoxy	26	32	107	656	126		299	126	962		92	46	198			328	1248	24	297		104	
Mecoprop	H	Phenoxy	103	32					171			71												
Mecoprop-P	H	Phenoxy				396								131				134			58			
Molinate	H	Thiocarbamate																		**0.1**				
Pendimethalin	H	Dinitroaniline					106																	952
Prochloraz	F	Amide								18					27									
Propanil	F	Anilide																		**0.1**				
Propiconazole	F	Conazole						1								8						2	14	
Prosulfocarb	H	Thiocarbamate		32			447																	
Sulphur	F	Inorganic Sulphur											131											
Tralkoxydim	H	Cyclohexanedione										**0.04**												
Trifluralin	H	Dinitroaniline															13							623

Source: Eurostat, 2007

* in bold numbers, highest dosage (in kg AS/ha) of chemical class used in production of cereals in 2003

(In the Table 1, F: fungicide, H: herbicide, I: insecticide, PGR: plant growth regulator)

Table 2. Top 5 AS used in production of fruit trees in 2003 (in tons)

AS	Type	Chemical Class	AT	BE	DE	DK	ES	FI	FR	GR	HU	IE	IT	LT	LV	NL	PL	PT	SE	SI	SK	UK
Amitrol	H	Triazole														20						
Captan	F	Phtalic Acid							191							62						
Chlorphyrifos-Methyl	I	Organophosphorus	16																		2	
Chlorpyrifos	I	Organophosphorus								42												15
Copper Oxychloride	F	Copper Compunds					**0.5**											**0.6**				
Copper Sulphate	F	Copper Compunds					**0.5**															
Cyprodinil	F	Pyrimidine												0.2	0.04					1		
Diazinon	I	Organophosphorus																		**0.3**		
Difenoconazole	F	Conazole												0.04	0.1							
Dimethoate	I	Organophosphorus									27											
Dinocap	F	Dinitrophenol																				2
Dithianon	F	Quinone	**1.1**	**1**		2		**1.8**				**0.04**					**0.2**		**0.9**			**1.1**
Diurno	H	Urea																				
Dodine	F	Aliphatic Nitrogen															51					
Fenhexamid	F	Anilide				2		**1.9**											**1**			
Fenthion	I	Organophosphorus								**2.3**												
Glufosinate	H	Organophosphorus						2														
Glyphosate	H	Organophosphorus			**1.5**		**0.2**			**0.6**	**0.6**							**0.5**		**1.6**	**0.6**	
Iprodione	F	Imidazole							74										4			
Kresoxim-Methyl	F	Strobilurine										**0.8**										
Mancozeb	F	Dithiocarbamate	52	77	208	33	144		365		107			3.3	0.5		198	62			8	
Methidathion	I	Organophosphorus									10											
Methiocarb	I	Carbamate						2														
Metiram	F	Dithiocarbamate			30								309								2	
Myclobutanil	F	Conazole										0.4										4
Parathion-Methyl	I	Organophosphorus								**2.3**												
Pyrimethanil	F	Pyrimidine	1																			
Sulphur	F	Inorganic Sulphur	18	21	454	7	373		1056	560	163		602			61			5	2	11	9
Tebufenpyrad	I	Pyrazole Phenyl										0.4										
Terbuthylazine	H	Triazine																		4		
Thiamethoxam	I	Nitroguanidine												**0.04**	**0.04**							
Thiram	F	Dithiocarbamate											417			59	64	40				
Tolyfluanid	F	Amine		**1.9**	**1.8**	3		**7.9**								**2.5**	**0.3**		**6.2**			
Ziram	F	Dithiocarbamate											487									

Source: Eurostat, 2007.

* in bold numbers, highest dosage (in kg AS/ha) of chemical class used in production of fruit trees in 2003.

(In the Table 2, F: fungicide, H: herbicide, I: insecticide, PGR: plant growth regulator)

Table 3. Use of AS in production of cereals (in % of the total AS used) in 2003

AS	AT	BE	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LV	NL	PL	PT	SE	SI	SK	UK
2,4-D	11.1		14.2			5.5	24.7			15.2	22.7		16.7	14.7	11.2		10.1				18.7	
Alpha-Cypermethrin	0.05			0.1							0.4										0.05	
Azoxystrobin														0.3								
Bentazone	0.9	0.5	1.6	1.9	0.6			0.1	0.04							0.2			0.6			0.05
Bromoxynil	2.7			0.1	2.6		0.4		0.1	4.2			1.4			0.1					0.1	0.2
Carbendazim	0.8	0.3	2.8	0.5			0.2		0.3		3	1.1	1.2				2.6				5	0.7
Carboxin				0.5									0.1									
Chlormequat		11.5	16.9	14.2				2.7	11.7								6.2					10.8
Chlorothalonil		0.6	0.1	1					0.2			8.3									0.2	1.3
Chlorpyrifos			0.7								0.2										2.2	1.2
Chlorpyrifos-Methyl		0.1																				
Chlorsulfuron			0.1				0.1			0.2							0.1					
Clopyralid			0.1						0.4												0.2	
Cyfluthrin									0.1													
Cyproconazole		0.4	0.5			0.3	0.1		0.3		0.4	0.1	0.2	0.2	0.2	0.1	0.2			0.7	0.9	1.1
Dicamba			0.5	0.05		7.9	0.2				1.7			4.8	2.1		2.5				3	
Dichlorprop	10.5	0.1		0.3					0.4													0.1
Diclofop							4.4		1.1	3.2			0.3					3.8				0.3
Difenoconazole			0.1	0.4	0.2		0.2		0.04		0.1									0.4	0.3	
Dimethoate		0.1		1.2	0.5			1			0.3		0.3			0.4	0.2				0.2	
Endosulfan											0.2											
Esfenvalerate				0.1															0.1			
Ethephon		0.2	0.2	1.7	0.4			0.6	1.1			0.8					0.7		0.1			0.3
Fenoxaprop-P	1.9	0.1	0.8		0.2		0.3	0.2	0.3	1.1			1.1				0.1		0.1		1.2	0.1
Fenpropidin	1.7		1.5	2.3	0.7	0.1		1.7	0.6			0.4		0.3	0.4	0.1	0.4			5.5		0.1
Fenpropimorph	1.7	2.1	4.7	3.1	3.4		0.1		2.3		2.6	5.4	0.5			3.1	1.9		0.5		0.5	2
Fluroxypyr	1.4	2.9	0.7	0.6	1.6		0.1		0.8		1.1		1.4	0.1	0.4	1.3	0.1		1.4	1.1	0.8	1
Flutriafol				0.4																		
Glyphosate		3.1	17.3	13	35	83.8	29.1	59	10	26.1	11.4	37.5	44	75.6	62.6	24.5	14.9	19.6	46.7	10.8	14.1	14.6
Imazalil								0.3											0.1			
Imazamethabenz	0.2	0.4	0.1				2.1		1.0	5.6			0.2									
Ioxynil	3.2	0.8		1.9	2.4		0.3		0.7				0.4			0.3						0.2
Iprodione													0.6									
Isoproturon	8.7	38.7	10.9	25.5			10.7		23.8		2.4	0.4	2.7			20.4	22.2	20.6	12.4	14.4	3.4	25.8
Linuron							0.1		0.5				0.1		6							

Mancozeb							1.9		0.1									3.2				
Maneb													0.1									
Mcpa	7.3	3.9	8	5.3	7.5		8.6	18	6.5	4.4	10.2	5.7	13.4		0.3	26.2	20.5	10.4	19.4		28.2	1.8
Mcpb																						0.04
Mecoprop	28.5	4	0.1	0.4			4.9		2.9	28.5	1.9		1.4			1.3	0.9				2.2	1.5
Mecoprop-P	3.3	2.7	0.1	3.2			0.1	1.5	1.7	0.2	2	16.2				10.7	0.1		3.8		0.4	4.2
Metazachlor																						0.1
Metiram																		0.2				
Metribuzin	0.2																0.1					
Molinate																		13.5				
Oxydemeton-Methyl									0.1													
Paraquat							0.1															0.1
Parathion-Methyl										3	0.1											
Pendimethalin	1.9	0.5	3.9	3.2	6.3		0.5		0.7			1.2	0.8			0.3	3.1	0.1			3.3	9.5
Pirimicarb		0.2			0.05				0.1										0.1	0.1		
Prochloraz	0.2	0.7	0.7				0.4	2.6	1.8			0.6	1.9				0.1		0.05		0.2	0.5
Propanil																		14.4				
Propiconazole	1.4	0.4	1.9	1.4	0.3	1.6		1.3	0.3		1.1	0.5	0.2	3	2	0.2	0.7		0.2	5	3.9	0.1
Quinoxyfen		0.04	0.5	0.1					0.1			0.2									0.4	0.2
Simazine																						0.1
Sulfur		0.7					0.1		4.8		14.6	0.1					2					0.05
Tebuconazole	2.4	1.2	0.6	1.6	1.5		0.3		2.0		1.3		1.7			0.7	0.8	0.1		0.05	1	0.7
Thiram													0.4				0.7			1.6		
Triadimenol			0.1	0.1				1.7	0.04		0.3					0.4	0.3				0.2	
Triasulfuron			0.1			0.1				0.1	0.1		0.1	0.1	0.1					0.5	0.1	
Tridemorph									0.4		2.1						1.3				2.1	
Trifluralin		2.1	3	0.2					0.8			0.6			12		0.8					6.2

Source: Eurostat

Table 4. Use of AS in production of fruit trees (in % of the total AS used) in 2003

AS	AT	BE	DE	DK	ES	FI	FR	GR	HU	IE	IT	LT	LV	NL	PL	PT	SE	SI	SK	UK
Amitraz					0.7						0.4			0.6	1.9	0.5				
Amitrol							0.9	2.4						5.3		1.2				
Atrazine								0.9	1.4											
Azinphos-Methyl						4.7					1.7						1.1			
Bentazone																	1.4			
Captan					0.7		8.3	0.6			4.1			16.6						
Carbaryl								0.5			1.2									
Carbendazim		1.6									1.5									
Chlorothalonil					1.1				1											
Chlorpyrifos					2.4		0.5	3.4	2.2		0.8				0.7	1.8				26.6
Chlorpyrifos-Methyl	17.3				0.9				0.8									3.9	6.2	
Copper Oxychloride					9.5											16.3				
Copper Sulphate					5.5															
Cyprodinil		0.6	0.9				0.6				0.5	4.1			2	0.7		4.2	0.9	
Diazinon																		32.3		
Dichlobenil		0.6																1.2		
Difenoconazole		0.9										1.2	12.2					1.2		
Dimethoate		1.3			2.8				6.2		0.9				2	3			0.5	
Dinocap									1.8									3.1	1.3	3.9
Dithianon	8.4	8		4.5		8.1									6.9		6.6			37.8
Diurno					3											0.6				
Dodine														2	6.6					
Endosulfan																		3.1		
Fenbuconazole											0.6									
Fenbutatin Oxide		0.6																		
Fenhexamid				4.5		8.6											7.1			
Fenthion								14.2												
Glufosinate						12.1														
Glyphosate			7.2		7.9		2.9	6.7	11.9		6.1				5.8	15.3		28.2	11	
Iprodione				1.7		4.6	3.2							2.7			13.3			2.5
Kresoxim-Methyl										88.6										
Mancozeb	54.1	32.4	21.1	66.2	5.8		15.8	2.1	24.4		4.6	91.1	86		25.8	15.1			26.4	
Mcpa					3						0.5			3	6.5					
Mecoprop														0.5						
Metazachlor															0.7					
Methidathion					1.2		0.7	1.5	2.4		1.6					1.8			2.5	

Methiocarb						13.3														
Methomyl					0.4															
Metiram			3		0.4		2.3	0.4	2.3		8.6			3.6	6.2	0.8			6.3	
Myclobutanil										9.9										6
Oxydemeton-Methyl			0.5																	
Oxyfluorfen					0.6															
Paraquat					2.8			1			0.8					2.9			1	
Parathion-Methyl			0.9		0.9		0.7	4.9			3.2									
Pendimethalin			0.6		0.7															
Phenmedipham						2.6														
Phosmet							1.3	0.6												
Pirimicarb		0.5	1.1											1.4	0.6				1	
Pyrimethanil	0.6	1.1				3.1								3	4.9	0.9				3.7
Simazine		3.8			0.5			1.9							1.7	2.3				
Sulfur	18.5	8.8	46.2	13.6	15		45.6	45.7	36.9		16.8			16.5		8.9	17.9	6.6	32.6	15.8
Tebuconazole											0.5				0.5					
Teflubenzuron																			0.9	
Thiram		5.7					1.9	0.9			11.6			15.9	8.3	9.7				
Tolyfluanid		15.4	9	6.9		35.1								11.8	10.8		43.6			
Triclopyr																1.4				
Ziram					1.9		1	2.3			13.6									

Source: Eurostat

Table 5. Characteristics of the AS used in production of cereals in 2003

AS	Group	Class	EC	Dir	WHO	B1	B2	B3	N1	N2	N3	N4	PMR	I1	I2	I3	I4	I5
2,4-D	H	Phenoxy	old	In	II	N	N	N	-	-	N	N	M	0.6115	0.67	0.5919	0.6115	0.6115
Alpha-Cypermethrin	I	Pyrethroid	old	In	II								M		0.67		0.4897	0.5620
Azoxystrobin	F	Strobilurine	new	In	U	N	M	N	-	+	S	V	L	0.8112	1	0.7575	0.8112	0.8112
Bentazone	H	Thiadiazine	old	In	III	N	N	N	-	-	N	N	H	0.7177	0.67	0.7273	0.7177	0.7177
Bromoxynil	H	Nitrile	old	In	II	T	T	N	-		V	V	VL	0.5086	0.67	0.4657	0.5086	0.5086
Carbendazim	F	Benzimidazole	old	In	U	T	M	N	-	+	M	H	M	0.6498	0.67	0.6447	0.6498	0.6498
Carboxin	F	Anilide	old	pending	U						M		VL	0.7109	0.43	0.8101	0.7048	0.6748
Chlormequat	PGR	Physiological	old	pending	III	N	T	N	-	-				0.6673	0.43	0.7510	0.6571	0.6481
Chlorothalonil	F	Aromatic	old	In	U	T	N	N	-	+	V	M	L	0.6883	0.67	0.6942	0.6883	0.6883
Chlorpyrifos	I	Organophosphorus	old	In	II	T	T	N	+	+	H	M	VL	0.5694	0.67	0.5433	0.5694	0.5694
Chlorpyrifos-Methyl	I	Organophosphorus	old	In	U	T	T	T	+	+	M	M	VL	0.5971	0.67	0.5820	0.5971	0.5971
Chlorsulfuron	H	Sulfonylurea	old	pending	U						N	S	H	0.6805	0.43	0.7635	0.7070	0.6492
Clopyralid	H	Pyridinecarboxylic Acid	old	In	U	N	N	N	-	-			VH	0.7429	0.67	0.7593	0.7429	0.7429
Cyfluthrin	I	Pyrethroid	old	In	II	T	T	N	+	+	V	V	E	0.5374	0.67	0.5035	0.5374	0.5374
Cyproconazole	F	Conazole	old	pending	III	T	N	N	-	-	S	M		0.6437	0.43	0.7184	0.6279	0.6279
Dicamba	H	Benzoic Acid	old	pending	III		N	M	-	-	S	S	VH	0.5911	0.43	0.6333	0.5911	0.5911
Dichlorprop	H	Phenoxy	old	Out	III						N		L	0.6185	0.1	0.8070	0.6583	0.6004
Diclofop	H	Aryloxyphenoxypropionic	old	pending	III								E		0.43		0.7330	0.6496
Difenoconazole	F	Conazole	old	pending	III	N	N	N	-	+	S	H		0.6921	0.43	0.7818	0.6676	0.6676
Dimethoate	I	Organophosphorus	old	In	II	T	T	T	+	+	S	M	M	0.4315	0.67	0.3669	0.4315	0.4315
Endosulfan	I	Organochlorine	old	Out	II			N	-	+	V	M	E	0.5725	0.1	0.7053	0.5725	0.5725
Esfenvalerate	I	Pyrethroid	old	In	II						V		VL	0.5396	0.67	0.4861	0.5129	0.5386
Ethephon	PGR	Physiological	old	In	U						N	N	E	0.9176	0.67	1.0000	0.8674	0.8374
Fenoxaprop-P	H	Aryloxyphenoxypropionic	old	pending	NL						M	H	E		0.43		0.6973	0.5754
Fenpropidin	F	Unclassified	old	pending	II	N			-	+				0.6268	0.43	0.6940	0.6261	0.6136
Fenpropimorph	F	Morpholine	old	pending	U	N	T	N	-	-				0.7326	0.43	0.8388	0.7146	0.7021
Fluroxypyr	H	Pyridinecarboxylic Acid	old	In	U	M	N	N	-	-	S	N		0.8310	0.67	0.8868	0.7823	0.7849
Flutriafol	F	Conazole	old	pending	III	N	N	N	-	+				0.6921	0.43	0.7818	0.6676	0.6676
Glyphosate	H	Organophosphorus	old	In	U	M	M	M	-	-	S	S	E	0.7969	0.67	0.8358	0.7969	0.7969
Imazalil	F	Conazole	old	In	II						M		VL	0.6431	0.67	0.6256	0.6696	0.6196
Imazamethabenz	H	Imidazolinone	old	Out	U						N		VH	0.5780	0.1	0.7480	0.6259	0.5680
Ioxynil	H	Nitrile	old	In	II	T	N	N	-	-	M			0.6172	0.67	0.5980	0.6038	0.6064
Iprodione	F	Imidazole	old	In	U	N	N	N	-	+	M		L	0.7888	0.67	0.8209	0.7888	0.7888
Isoproturon	H	Urea	old	In	III	N	N	N	-	-				0.8017	0.67	0.8470	0.7583	0.7609

Linuron	H	Urea	old	In	U				-	+	M	M	M	0.7061	0.67	0.7093	0.7279	0.6700
Mancozeb	F	Dithiocarbamate	old	In	U	T	T	N	-	+	M	N	L	0.6688	0.67	0.6709	0.6688	0.6688
Maneb	F	Dithiocarbamate	old	In	U	M	T	N	-	+	M	H	L	0.6786	0.67	0.6825	0.6786	0.6786
Mcpa	H	Phenoxy	old	In	III						S	S	H	0.6544	0.67	0.6364	0.6856	0.6277
Mcpb	H	Phenoxy	old	In	III						M	S	H	0.6285	0.67	0.6015	0.6653	0.6075
Mecoprop	H	Phenoxy	old	In	III								H		0.67		0.6734	0.5872
Mecoprop-P	H	Phenoxy	old	In	III		M	N	-	-				0.7477	0.67	0.7750	0.6900	0.7159
Metazachlor	H	Anilide	old	pending	U		N	N	-	-				0.8046	0.43	0.9348	0.7595	0.7621
Metiram	F	Dithiocarbamate	old	In	U	T	T	N	-	-	N	M	E	0.7669	0.67	0.7983	0.7669	0.7669
Metribuzin	H	Triazinone	old	In	II						S	S	H	0.5869	0.67	0.5442	0.6316	0.5737
Molinate	H	Thiocarbamate	old	In	II						S	M	M	0.5970	0.67	0.5597	0.6401	0.5823
Oxydemeton-Methyl	I	Organophosphorus	old	Out	Ib						S	H	H	0.3080	0.1	0.3822	0.2788	0.3538
Paraquat	H	Bipyridylium	old	Out	II						S	S	E	0.5713	0.1	0.7458	0.6214	0.5635
Parathion-Methyl	I	Organophosphorus	old	Out	Ia	T	T	T	+	+			VL	0.2557	0.1	0.3030	0.2557	0.2557
Pendimethalin	H	Dinitroaniline	old	In	III				-	+	M		VL	0.7106	0.67	0.7179	0.7315	0.6736
Pirimicarb	I	Carbamate	old	In	II	N	M	N	-	-	N		M	0.5815	0.67	0.5544	0.5815	0.5815
Prochloraz	F	Amide	old	pending	III	T	T	N	-	+			M	0.5332	0.43	0.5634	0.5332	0.5332
Propanil	H	Anilide	old	pending	III						M	S	E	0.7053	0.43	0.8031	0.7277	0.6699
Propiconazole	F	Conazole	old	In	II	T	T	N	-	-	M	M	M	0.5320	0.67	0.4936	0.5320	0.5320
Quinoxyfen	F	Quinoline	new	In	U	N			-	-				0.9528	1	0.9348	0.9000	0.8875
Simazine	H	Triazine	old	Out	U	N	N	N	-	-	S	S	H	0.6463	0.1	0.7971	0.6463	0.6463
Sulfur	F	Inorganic Sulfur	old	pending	U	T	T	M	-	-	N	N	L	0.5860	0.43	0.6334	0.5860	0.5860
Tebuconazole	F	Conazole	old	pending	III	N	T	N	-	+	M	H	M	0.5730	0.43	0.6125	0.5730	0.5730
Thiram	F	Dithiocarbamate	old	In	III	T	T	N	-	+	H	H	L	0.5743	0.67	0.5494	0.5743	0.5743
Triadimenol	F	Conazole	old	pending	III	N	N	N	-	-	S		M	0.6937	0.43	0.7651	0.6937	0.6937
Triasulfuron	H	Sulfonylurea	old	In	U		N	N	-		N	S		0.8670	0.67	0.9348	0.8123	0.8149
Tridemorph	F	Morpholine	old	Out	II	N	N		-	+				0.5410	0.1	0.6940	0.5535	0.5410
Trifluralin	H	Dinitroaniline	old	Out	U						H	M	VL	0.5926	0.1	0.7752	0.6398	0.5820

Sources: EC, WHO, IOBC, PAN, NPIC

(In Table 5, EC: time of placement an AS on the market before/after 1993, Dir: status of an AS in the Annex 1 of the Directive 91/414/EEC, WHO: hazardousness of an AS for human health, B1: side effects on predatory mites, B2: side effects on parasitoids, B3: side effects on lacewings, N1: absence/presence of toxicity to bees, N2: absence/presence of toxicity to fishes, N3: toxicity to fishes, N4: toxicity to zooplankton, PMR: potential risk for ground water – pesticide movement ranking, I1: average score attained without imputation, I2: average score obtained for normative aspects, I3: average score obtained for potential hazardousness, I4: average score obtained when assuming average imputation, I5: average score obtained when assuming median imputation)

For meaning of the classes corresponding to each variable see in the section 3.1.2.4.

Table 6. Characteristics of the AS used in production of fruit trees in 2003

AS	Group	Class	EC	Dir	WHO	B1	B2	B3	N1	N2	N3	NS4	PMR	IP	I1	I2	I3	I4	I5
Amitraz	I	Amidine	old	out	III	T	T	M	-	+	M	S	VL		0.4887	0.2710	0.5889	0.4887	0.4887
Amitrol	H	Triazole	old	in	U	T	M	T	-	+	N	S	M		0.6169	0.6244	0.6042	0.6169	0.6169
Atrazine	H	Methylthiotriazine	old	out	U	N	M	N	-	-	S	S	H	restricted	0.5945	0.2283	0.7791	0.5945	0.5945
Azinphos-Methyl	I	Organophosphorus	old	out	Ib	T	T	T	+	+	H	M	L		0.3066	0.2710	0.3168	0.3066	0.3066
Bentazone	H	Thiadiazine	old	in	III	N	N	N	-	-	N	N	H		0.7026	0.6244	0.7416	0.7026	0.7026
Captan	F	Phtalic Acid	old	in	U	N	M	N	-	+	H	M	VL		0.7464	0.6244	0.7967	0.7464	0.7464
Carbaryl	PGR	Carbamate	old	out	II	M	T	T	+	+	M	M	L	prohibited	0.3253	0.1000	0.4323	0.3253	0.3253
Carbendazim	F	Benzimidazole	old	in	U	T	M	N	-	+	M	H	M	restricted	0.6375	0.5817	0.6575	0.6375	0.6375
Chlorothalonil	F	Aromatic	old	in	U	T	N	N	-	+	V	M	L		0.6835	0.6244	0.7023	0.6835	0.6835
Chlorpyrifos	I	Organophosphorus	old	in	II	T	T	N	+	+	H	M	VL		0.5664	0.6244	0.5267	0.5664	0.5664
Chlorpyrifos-methyl	I	Organophosphorus	old	in	U	T	T	T	+	+	M	M	VL		0.6031	0.6244	0.5769	0.6031	0.6031
Copper oxychloride	F	Copper Compounds	old	pending	III	N	N	N	-	+	S	V			0.6472	0.4756	0.7559	0.6445	0.6373
Copper Sulphate	F	Copper Compounds	old	pending	II						S		M		0.5457	0.4756	0.5968	0.5778	0.5455
Cyprodinil	F	Pyrimidine	old	in	NL						M		M			0.6244		0.6699	0.5644
Diazinon	I	Organophosphorus	old	out	II	T	M	M	+	+	M	H	L		0.4093	0.2710	0.4713	0.4093	0.4093
Dichlobenil	H	Nitrile	old	pending	U						S	M	M		0.6525	0.4756	0.7746	0.6656	0.6333
Difenoconazole	F	Conazole	old	pending	III	N	N	N	-	+	S	H			0.6652	0.4756	0.7863	0.6603	0.6531
Dimethoate	I	Organophosphorus	old	in	II	T	T	T	+	+	S	M	M		0.4564	0.6244	0.3627	0.4564	0.4564
Dinocap	F	Dinitrophenol	old	in	III						H	V	VL		0.6234	0.6244	0.6166	0.6412	0.6121
Dithianon	F	Quinone	old	pending	III	N	N	N	-	+	H				0.6292	0.4756	0.7255	0.6288	0.6216
Diuron	H	Urea	old	out	U						S	S	M	restricted	0.5712	0.2283	0.8083	0.5974	0.5651
Dodine	F	Aliphatic Nitrogen	old	pending	III						N	M	E		0.6843	0.4756	0.8268	0.7216	0.6621
Endosulfan	I	Organochlorine	old	out	II			N	-	+	V	M	E	prohibited	0.4960	0.1000	0.6885	0.4960	0.4960
Fenbuconazole	F	Conazole	old	pending	U						M	H	M		0.6143	0.4756	0.7071	0.5729	0.6018
Fenbutatin Oxide	I	Organotin	old	pending	U						H	V	L		0.6012	0.4756	0.6810	0.5345	0.5919
Fenhexamid	F	Anilide	new	in	U	N			-	+	M	M			0.8605	0.8290	0.8785	0.8317	0.8245
Fenthion	I	Organophosphorus	old	out	II						M	V	L		0.4119	0.2710	0.5032	0.4639	0.4348
Glufosinate	H	Organophosphorus	old	in	III	T	M	M	-	-			L		0.6438	0.6244	0.6468	0.6438	0.6438
Glyphosate	H	Organophosphorus	old	in	U	M	M	M	-	-	S	S	E		0.7642	0.6244	0.8235	0.7642	0.7642
Iprodione	F	Imidazole	old	in	U	N	N	N	-	+	M		L		0.7660	0.6244	0.8298	0.7660	0.7660
Kresoxim-Methyl	F	Strobilurine	new	in	NL	N	N	N	-	+	S	V	M		0.7359	0.8290	0.6684	0.7708	0.6945
Mancozeb	F	Dithiocarbamate	old	in	U	T	T	N	-	+	M	N	L	restricted	0.6494	0.5817	0.6738	0.6494	0.6494
Mcpa	H	Phenoxy	old	in	III						S	S	H		0.6435	0.6244	0.6612	0.5972	0.6261
Mecoprop	H	Phenoxy	old	in	III								H			0.6244		0.5540	0.5946
Metazachlor	H	Anilide	old	pending	U		N	N	-	-					0.7597	0.4756	0.9393	0.7399	0.7363
Methidathion	I	Organophosphorus	old	out	Ib	T	T	T	+	+	M	S	L		0.3066	0.2710	0.3168	0.3066	0.3066
Methiocarb	I	Carbamate	old	in	Ib						H	H	VL		0.5166	0.6244	0.4389	0.5535	0.5244

Methomyl	I	Oxime Carbamate	old	out	Ib	T	T	T	+	+	M	H	H		0.2634	0.2710	0.2556	0.2634	0.2634
Metiram	F	Dithiocarbamate	old	in	U	T	T	N	-	-	N	M	E	restricted	0.7241	0.5817	0.7845	0.7241	0.7241
Myclobutanil	F	Conazole	old	pending	III	N			-	-	M	H	M		0.6265	0.4756	0.6980	0.6265	0.6265
Oxydemetonmethyl	I	Organophosphorus	old	out	Ib						S	H	H		0.3367	0.2710	0.3822	0.4005	0.3714
Oxyfluorfen	H	Diphenyl Ether	old	pending	U						H		E		0.6708	0.4756	0.7975	0.6799	0.6508
Paraquat	H	Bidpyridylium	old	out	II								E			0.2710		0.5554	0.5095
Parathion-Methyl	I	Organophosphorus	old	out	Ia	T	T	T	+	+			VL		0.2764	0.2710	0.2709	0.2764	0.2764
Pendimethalin	H	Dinitroaniline	old	in	III				-	+	M		VL	restricted	0.6568	0.5674	0.7179	0.6144	0.6399
Phenmedipham	H	Bis Carbamate	old	in	U						S		VL		0.7821	0.6244	0.8911	0.7749	0.7426
Phosmet	I	Organophosphorus	old	in	II	T	T	N			M	H	L		0.5448	0.6244	0.4961	0.5448	0.5448
Pirimicarb	I	Carbamate	old	in	II	N	M	N	-	-	N		M		0.5839	0.6244	0.5577	0.5839	0.5839
Pyrimethanil	F	Pyrimidine	old	in	U	N	T	N	-	-					0.7603	0.6244	0.8433	0.7429	0.7357
Simazine	H	Triazine	old	out	U	N	N	N	-	-	S	S	H	restricted	0.6200	0.2283	0.8181	0.6200	0.6200
Sulfur	F	Inorganic	old	pending	U	T	T	M	-	-	N	N	L	restricted	0.6050	0.4329	0.6843	0.6050	0.6050
Tebuconazole	F	Conazole	old	pending	III	N	T	N	-	+	M	H			0.5902	0.4756	0.6599	0.5935	0.5863
Teflubenzuron	I	Benzoylurea	old	pending	U	N	N	N	-	-					0.7597	0.4756	0.9393	0.7485	0.7363
Thiram	F	Dithicarbamate	old	in	III	T	T	N	-	+	H	H	L	restricted	0.5661	0.5817	0.5478	0.5661	0.5661
Tolyfluanid	F	Amide	old	in	U	M	T	N	-	+					0.6958	0.6244	0.7345	0.6859	0.6787
Triclopyr	H	Pyridyloxyacetic	old	in	III				-	+	M		L		0.6556	0.6244	0.6765	0.6669	0.6378
Ziram	F	Dithiocarbamate	old	in	III						H	H	M	restricted	0.5742	0.5817	0.5676	0.5992	0.5700

Sources: EC, WHO, IOBC, PAN, NPIC

(In Table 6, EC: time of placement an AS on the market before/after 1993, Dir: status of an AS in the Annex 1 of the Directive 91/414/EEC, WHO: hazardousness of an AS for human health, B1: side effects on predatory mites, B2: side effects on parasitoids, B3: side effects on lacewings, N1: absence/presence of toxicity to bees, N2: absence/presence of toxicity to fishes, N3: toxicity to fishes, N4: toxicity to zooplankton, PMR: potential risk for ground water – pesticide movement ranking, IP: recommendations of AS use under IP, I1: average score attained without imputation, I2: average score obtained for normative aspects, I3: average score obtained for potential hazardousness, I4: average score obtained when assuming average imputation, I5: average score obtained when assuming median imputation)
For meaning of the classes corresponding to each variable see in the section 3.1.2.4.

17.2. Annex 2. Experts opinions about variables used to build a pesticide use indicator

We have received 32 answers and commentaries from 40 experts that are involve in ENDURE .

To the question if the variables are suitable to asses pesticide use “safety”[7], 27 experts rated the suitability of the seven chosen variables as summarized in the Table 1.

Table 1. Summarized valuation of the variables according with experts opinion

Variable	**Description of the Variable**	**YES**	**NO**
EC-Status	Authorisation status	74.1%	18.5 %
WHO	Hazardousness for Health	88.9%	11.1 %
IOBC-B	Toxicity for Beneficial Organisms	92.6%	7.4 %
IOBC/PAN	Toxicity for Natural Species	85.2%	11.1 %
PMR	Potential Pollution of Groundwater	74.1%	22.2 %
WS	Solubility in Water	44.4%	40.7 %
IP	Recommended Use in Integrated Production	48.1%	37.0 %

- To the question if other variables should be included, the experts suggested the following variables:

Risk and safety phrases
Treatment frequency index
Half life indicator
Volatilisation
Biodegradation
Degradation products of the pesticide
Persistence in soil
Aquatic toxicity
EEP-air environment exposure to pesticides
Toxicity for earth worms
Toxicity for partridges
Persistence (length of stay in the environment)
Vapour pressure (for emission to the air)
Fat solubility
Toxicity for protected animals (e.g. honey bees)
Spraying technique efficiency (machinery and technology)
Yearly load or number of maximum applications of effective dose (AS/ha) per year
Potential for resistance

- To the question about the relevance of each variable, 23 different weighting factors distributions were submitted. The average weightings factors are included in the

[7] The term Safety was initially thought to be appropriated to define pesticide use innovation, which is evaluated according with properties and characteristics of AS applied in crop production, but from the survey on experts opinion was made clear that the word is inappropriate and even not included within the FAO Pesticide Code of Conduct.

Table 2 for six variables in production of cereals and seven variables in production of fruit trees.

Table 2. Weighting factors assigned to each variable

	Variable	Weighting Factor Cereals	Weighting Factor Fruit Trees
1	EC – Status	21.8 %	21.4 %
2	WHO	21.3 %	20.5 %
3	IOBC-B	18.3 %	16.2 %
4	IOBC/PAN	16.6 %	13.1 %
5	PMR	15.0 %	10.8 %
6	WS	7.1 %	4.7 %
7	IP	-	13.3 %

- Commentaries about each variable proposed:

Authorisation status

Only authorised active substances can be applied
Safety assessment for registration takes into account hazardousness for human health, toxicity for beneficial organisms and natural species, potential pollution of groundwater and solubility in water in balance with actual exposure during adequate condition of utilization
Authorisation process is based on assessment of safety of the use of pesticides
Is not clear the aim of including time existing on the market, often long existence is an indication of high risk
Old pesticides are not always risky pesticides
This variable is not gradual
The use of this variable would imply that all the AS that are listed have the same impacts
The information has been already complied with the directive 91/414 and its updates
This is not a good indicator, risk assessment assumes every one does good agricultural practices

Hazardousness for human health

It is a requirement when applying for an authorisation
It is not relevant, if wearing protective clothing
This only relate to acute mammalian toxicity and misses out chronic effects
There is a need to include other chronic effects such as generation of cancer

Toxicity for beneficial organisms

More than three species should be considered
Overlaps with toxicity for natural species

Toxicity for natural species

Overlaps with toxicity for beneficial organisms
Combination effects should be considered (mixtures in ecosystems)

Potential pollution of groundwater

Is not a relevant indicator
This variable is important in case of misuse of active substances

The environmental part is less important
Pollution of groundwater is used as part of Danish authorisation process
Does not sound scientifically
Depends on the type of crop
Superficial water is also important because of biodiversity and drinking water

Solubility in water

Is not a relevant indicator for safety
Pesticide movement rating is more relevant
To be related to soil type and prevailing weather conditions around application time
It is relevant for humid regions, effects are not similar in different areas

Recommended use in integrated production

This classification is based on toxicity for beneficial organisms and natural species
It is an option if other variables are not available
Depend on the reason of the recommendations
This variable is not gradual
A recommendation is not always scientifically based
It is already integrated in good agricultural practices
Many impacting parameters already
Only in case that IP is broadly accepted, certified and controlled as an EU standard production scheme

- **Other commentaries and suggestions include**:

An heterogeneous indicator is not relevant
Innovation may be associated to use of products with different modes of action (towards avoiding development of pest resistance to pesticides)
Equal index values may have very different effects on the variables defining the index, then it will be helpful to increase political acceptance of pesticide use, but not to promote improvements in environmental variables
Variables that consider a single pesticide characteristic could be valuable in specific conditions or locations
To add use of quantities applied of products with low and high hazard lead to distortions, an alternative is to calculate a risk figure for each pesticide applied that reflects both hazard and dosage
The word safety is the context of measuring risk is strongly discouraged by FAO
Authorisation in a country may differ to the present EU policy (e.g. DK)
Persistence in soil is important in Nordic regions
One criteria that exceeds the valuation ranks can make a product unacceptable
To build risk indicators is success less (e.g. DK)
An approach based on growing pollution points (as implemented in NL) might be a better way to go
To assess safety, valuations of both hazards and exposure should be taken into account
The assessment of the safety of the use of pesticides is a quite complex exercise
Through use of sophisticated modelling, in several projects is aimed to work on risk indicators, but the interpretation of the results still being a problem even when those results contain useful information

- **Conclusions**

From the proportion of answers submitted by experts, it might be said that in the calculation of a pesticide use indicator, the relevance of the variables toxicity for beneficial organism (92.6 %), hazardousness for human health (88.9 %) and toxicity for natural species (85.2 %) is in average high, while the suitability of authorisation status (74.1 %) and potential pollution of groundwater (74.1%) is acceptable, but the inclusion of the variables recommendations of use in IP (48.1 %) and solubility in water (44.4 %) might be debatable. In the Figures 1 , the results of the survey to the question if the variables selected are suitable or not are depicted.

In the assignation of weighting factors to the variables chosen to build a pesticide use indicator, the authorisation status and the hazardousness for human health resulted as the most important variables, contrarily the variable water solubility was catalogued as the less important, while to the remaining variables (toxicity for beneficial organisms, toxicity for natural species and potential pollution of groundwater), an intermediate significance was given. It is important to mention that the variable recommendation of use in IP, which is only taken into account for production of fruit trees has also an middle importance.

In the Figure 2, the average weighting factors for the chosen variables obtained from the EOS are depicted. In production of cereals six variables are included , while for production of fruit trees seven variables are taken into account.

In the Figures 1 and 2, authorisation status (EC), hazardousness for human health (WHO), toxicity for beneficial organism (B), toxicity for natural species (NS), potential pollution of groundwater (PMR), solubility in water (WS) and recommendations of use in IP (IP).

Figure 1. Suitability of the variables chosen to assess pesticide use innovation according to experts opinion

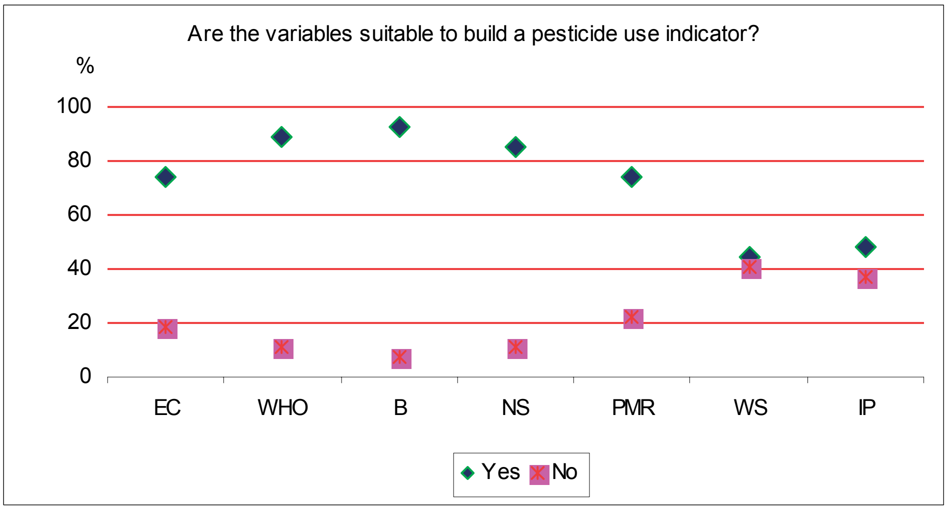

Figure 2. Weighting factors for the variables chosen to assess pesticide use innovation according to experts opinion