ENDURE

European Network for Durable Exploitation of crop protection strategies

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FOOD and Quality and Safety

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SWOT analysis of existing MBCSs in the four regions

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PU Public	**X**
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)	

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Glossary

Definitions used in this study

ENDURE	European Network for Durable Exploitation of crop protection strategies
MBCS	Maize Based Cropping System
IPM	Integrated Pest Management
IP/IF	Integrated Production/Integrated Farming
CS	Case Studies
MCS	Maize Case Study
ECB	European Corn Borer, *Ostrinia nubilalis*
MCB	Mediterranean Corn Borer, *Sesamia nonagioides*
WCR	Western Corn Rootworm, *Diabrotica virgifera virgifera* LeConte

Summary

Maize-based cropping systems (with different shares of maize crops in the rotation) are dominant in European arable systems. Maize cultivation (either grain or green crop) itself covers an area of 14-15 million hectares in EU-27 (between 2007 and 2009) (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home). The pesticide load is generally high (though different in type of active ingredients and target). These systems may involve other crops (e.g. winter cereals, sunflower, soybean) and are infested by important pests such as weeds (competitive species as well as invasive and/or allergenic ones), aphids, soil insects, the quarantine Western Corn Rootworm (*Diabrotica virgifera virgifera* LeConte), other Lepidoptera species and pathogens such as *Fusarium* species. Mycotoxins potentially produced by phytopathogenic fungi have serious food and feed safety implications. New challenges (increased maize acreages, continuous cultivation, economic aspects, GM maize, etc.) should be considered in IPM/IF as well. MBCS analysed crop protection issues in maize based cropping systems of four reasonably homogeneous (from the maize cropping systems point of view) European Regions. Building up from the work done in the MCS, identified economic pest problems as well as current and advanced pest control practices, characterising the pesticide load, finding bottlenecks of existing MBCS and performing a SWOT analysis on the current systems. This deliverable serves and demonstrates an intermediate stage of IPM status in MBCSs towards innovative IF/IP with general and regional recommendations on IF in MBCSs.

Teams involved:

SZIE - Szent István University, Hungary
CNR - National Research Council, Italy
SSSUP - Scuola Superiore Saint' Anna, Italy
UdL - University of Lleida, Spain
ACTA - Arvalis Institute du Vegetale, France
AU - Aarhus University, Denmark
PPO - Wageningen University and Res. Center, Appl. Plant Production, The Netherlands
IHAR - Plant Breeding and Acclimatisation Institute, Poland

Geographical areas covered:

We selected **four regions** from European maize cultivation areas (in Hungary, Italy, France/Spain and Poland/Denmark/Holland, see map below) that represent the range of various geographic, climatic and cultivation types as follows:

Hungary: Maize, grain, non-irrigated, rotated or non-rotated under continental climate.
Italy: Maize, grain/silage, irrigated/non-irrigated, continuous/rotated in Po Valley
Spain and France: Maize incl. GM Bt maize, irrigated, grain (rotated), silage non-rotated, in Ebro Valley Spain), Maize grain or silage, irrigated, rotated or non-rotated, France
North (The Netherlands, Poland and Denmark): Maize, silage, non-irrigated, rotated/non-rotated

Regions selected for SWOT analysis of MBCSs

MBCS Core Team developed a template for the Expert Based Survey – EBS (see on page 8). The following procedure was adopted by all partners:

- selected typical MBCSs in a given region, i.e. representing the most widespread maize systems and farming practices,
- focused on key pest (arthropods, diseases and weeds) problems;
- considered the regions as "flexible spatial units" to allow the determination of the main maize cropping system(s) and key pests in the region.

Based on the above survey SWOT analysis of systems was performed. Preliminary results were presented and discussed during a Workshop (Pau, July 2009). Draft reports were presented and discussed at the Annual Meeting in October 2009.

Conclusions

- Maize is a key crop in the MBCS either in terms of their acreages, frequency or role (breaking cultivation of other crops) in the rotation system.
- Economic driving forces are key factors for triggering farmers' decision on cultivation. However, depending on national/regional policies, disadvantages and benefits of a multi-year approach (involving more crops in rotation if favour of sustainable farming) are not frequently considered by farmers or available for implementation.
- MBCSs should and can be analysed and IPM/IF/IP proposed in a regional (natural and policy and societal) context, so that priorities could be set and development proposed accordingly.
- Complex (environmental, technical, economic, etc.) policy aim weighted evaluation methods for various options for MBCSs development scenarios are still missing.

1. State of the art

Maize is one of the most important European crops covering an area of 14-15 Mha in EU-27 (between 2007 and 2009) (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home) and the pesticide input (especially herbicides) is rather high. Maize is cultivated for different kinds of production purposes, such as grain for food, feed and processing, seed and green maize (silage and biogas). Therefore, a more sustainable maize production based on a reduction of pesticide use/load (varying over regions depending on target pests, diseases and weeds) offers significant impact at EU level. In this context, the introduction of innovations such as genetic modification for tolerance and resistance might be considered for future benefits.

Results from the Maize Case Study (DR3.7 and DR1.18 and 1.19) give broad insight on pest, disease and weed problems as well as pesticide use in Europe. However, these deliverables point out that to make maize production more sustainable the whole cropping system, i.e. including the cropping sequence, rather than the single crop should be considered.

More sustainable cropping systems may involve other crops such as winter and dicot crops which increase the overall diversity of the cropping system. Therefore the crop protection strategy must be planned considering all important pests such as aphids, soil insects, the quarantine *Diabrotica virgifera virgifera*, Lepidoptera species, pathogens such as *Fusarium* species and weeds (competitive species as well as invasive, allergenic and herbicide resistant ones). An important issue is also related to mycotoxins and food safety. New challenges (increased maize acreages, continuous cultivation, economic aspects, GM maize, etc.) should be considered in IPM/IF.

MBCS activities aimed at identification of economic pest problems, pest control practices in the selected regions, characterise pesticide load, determined bottlenecks at system level of existing MBCS including advanced plant protection methods (i.e. IPM tools already available but not widely used in practice) and analysing the overall information in order to be able to proceed (subsequent deliverable) and consider innovative MBCS (i.e. IPM tools based on innovations still not available). The main aim of this Deliverable is the SWOT analysis of current MBCS in the four regions.

2. Harmonization of material and methods among the Network

In order to properly address plant protection in maize crops stands, previous crops(s), subsequent crop(s) and their various management practices should be considered. Thus, instead of a single crop, cropping systems where maize has a key role (i.e. at least 50% - Maize Based Cropping System, MBCS) have been analysed across four important and diverse maize producing European areas: Hungary, northern Italy, south-western France /northern Spain, and a northern region encompassing Poland/Denmark/The Netherlands.

Table 1. Area of grain maize in the countries involved in the MBCS.

CROP_PRO: Grain maize **STRUCPRO:**Area of production (1000 ha)

geo \ time	2007A00	2008A00	2009A00
European Union (2...	8286.9	8855.9 (p)	8430.0 (p)
Denmark	–	–	–
Spain	361.0	366.1 (p)	341.9 (p)
France	1530.7	1758.5	1748.9
Italy	1053.4	991.5	943.4
Hungary	1078.8	1191.8	1166.6
Netherlands	19.3	22.1	19.0
Poland	262.0	317.2	273.9 (p)

Table 2. Area of "green" maize in the countries involved in the MBCS.

CROP_PRO: Green maize **STRUCPRO:**Area of production (1000 ha)

geo \ time	2007A00	2008A00	2009A00
European Union (2...	5008.5 (p)	5161.1 (p)	:
Denmark	144.6	157.8	:
Spain	92.1	75.4 (p)	93.1 (p)
France	1332.0 (p)	1407.2	1410.1
Italy	275.4	275.7	223.7
Hungary	141.0	94.4	74.1
Netherlands	221.6	243.4	240.0
Poland	367.5	415.7	:

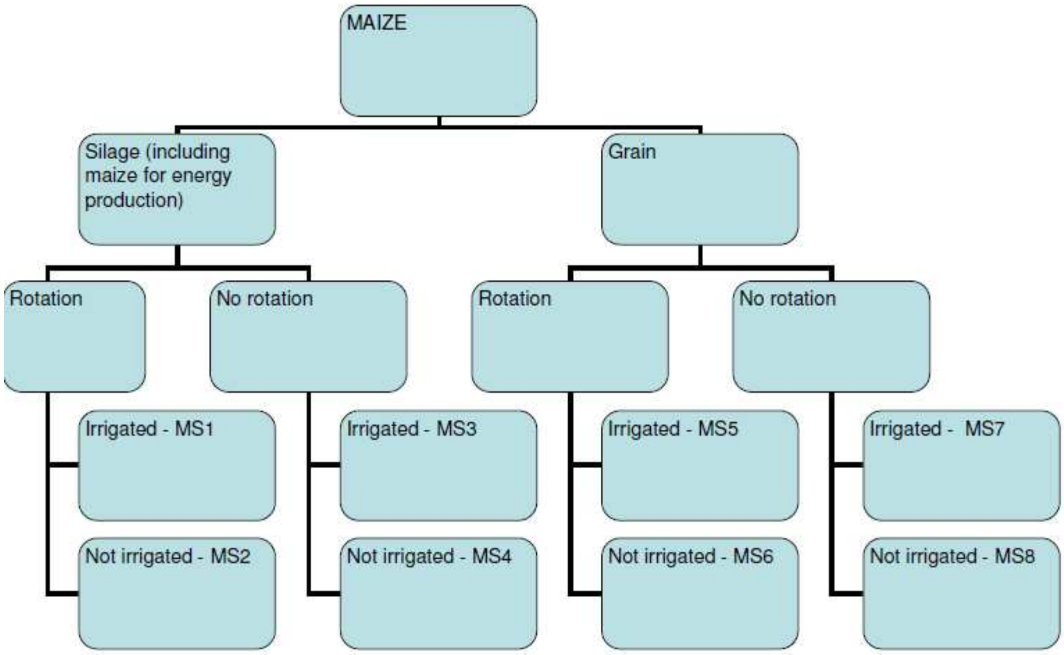
Source: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home

A Core Group was established with a representative from each of the four regions (SZIE, CNR, AU, ACTA) plus an expert on social assessment (SSSUP), with the task of governing the activities and maintaining continuous communication. Additional experts from other partners were invited to contribute and attended the workshops.

The approach was based on expert interviews, therefore a template was developed.

There are many maize based cropping systems in Europe, therefore to make the information collected in the four regions comparable, a common categorisation of the system was needed. MBCSs could be grouped on the basis of various parameters but the 3 most important ones that highly determine the characteristics of the system and its IPM are:

- grain (food and feed, processing, seed, sweet) or green (mainly silage) maize
- crop rotation or continuous maize (for 2 or more consecutive years)
- irrigated or not-irrigated



Based on this and partly benefiting from the prior CSs (maize, winter wheat) current and advanced MBCS of the four regions were evaluated. SWOT analysis was then performed for the current systems. In addition to technical parameters, socio-economic aspects were also considered.

Region	x = current measure of minor importance	x = innovative measure which will likely be of minor importance	Please add other pest control measures if you think they are important in your region
Maize System	X = current measure of major importance	X = innovative measure with potential to be of major importance	Yellow part is the first part of the excercise where we need to describe how the main Maize Systems are managed at the moment (based on information for the interviews performed by the maize case study and expert knowledge.
	with 'importance' it is meant that this measure is either used at large scale, by most farmers, or that it is very effective to control the pest in a wide variety of conditions.		

Pest	Pest control measures															
	preventive measures					Mechanical measures			Cultural measures					Chemical measures		
	false seedbed	removal of crop residues	field margin management	stimulation of mycorrhizal infection of crop	effort made for early detection in order to have better pest control	major tillage (ploughing)	minor tillage (harrowing etc.)	biological control (removal of pest)	crop resistance	crop choice in rotation	variety choice (only related to maize)	Early sowing (only related to maize)	plant nutrition	biocide	synthetic pesticides by spraying	seed treatments
Diseases (fungal, bacterial, virusses)																
D1																
D2																
D3																
Dn																
Group 1																
Group 2																
Group 3																
Arthropods																
A1																
A2																
A3																
An																
Group 1																
Group 2																
Group 3																
Weeds																
major weed 1																
major weed 2																
major weed 3																
major weed 4																
major weed 5																
Group1																
Group 2																
Group 3																

3. SWOT analysis of MBCS by Partners

3.1. SWOT analysis of MBCS in selected Hungarian regions

Regions of Tolna and Bekes County (Hungary)
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INTRODUCTION
Arable crops are cultivated on a total of 4,600,000 ha and from this area maize is cultivated on 1,28 Mha in Hungary. Grain maize is cultivated on 1,11 million ha, 0,10 million ha is silage, while 0,08 million ha is cultivated for sweet and seed maize.

Altogether 1,50 million ha of arable land is used under Agri-Environmental Programs (AEPs). From this 1,08 million is under different programs for arable crops, and among this 0,23 million ha is under Integrated Production of Arable Crops (IP/IF) in Hungary. We should notice that IPM is often used is Europe but the meaning thereof might be vary different. In our analysis, we will use IPM strictly for those cultivation systems that are defined by specific requirements under national Agri-Environmental Programs. The requirements set up in these programs for Integrated Production are very close to that of IOBC wprs quidelines.

There were 2 somewhat different AEPs, one from 2004 to August of 2009, while the other from September 2009. One important difference is the first one envisaged obligatory rotation of maize from one year to another, while the second one allows 3 years cultivation on the same field (unless WCR larvae has been detected on the field) (also see later).

There is no officially available exact data on the area of integrated maize production in Hungary. However, if we rely on the data above, we can calculate, that IPM maize production should be conducted on about 0,06 million hectares.

NATIONAL REGULATIONS REGARDING KEY PESTS OF MAIZE
European Corn Borer (*Ostrinia nubilalis*)
National regulation for ECB is legislated by Ministerial decree (FVM 5/2001) that says as follows: “Maize, millet and hemp stalks have to be plough down into the soil or have to be destroyed on other ways latest by April 15 in subsequent year.” This measure will result in destroying overwintering larvae in maize stalks.

Western corn rootworm, WCR (*Diabrotica virgifera virgifera* LeConte)
National regulation for WCR is covered by Ministerial Decree (FVM 7/2001) that says as follows:
“If a maize field is infested by WCR larvae, maize can not be produced on the field in the subsequent year.” Practically, this decree allows planting second year maize, since WCR larvae are generally not found in first year maize, thus second year maize can be planted but third year one not (if again the field is infested by WCR larvae).
Regulation of continuous maize production
Maize can be cultivated maximum 3 years subsequently based on the regulations of cross compliance (2nd AEPs from 2009 autumn).
Agri-Environmental Programs (Integrated Plant Protection/IF/IP)
Agri-environmental programs, and among them Integrated Pest Management were first issued in 2004 Hungary. New program of AEP was issued in 2009. Significant number of

farmers joined these programs. Farmers receive premium (subsidies) if they follow the specific rules of Integrated Production or Organic Farming.
In AEPs cropping system and crop rotation is legislated. In first AEP program (2004-2009) continuous production of maize was prohibited, but in recently issued program there is no regulation on continuous maize production. However, the area of maize, winter wheat and sunflower should not extend 60% on farm level.

REGIONAL CHARACTERISTICS OF CROP (MAIZE) PRODUCTION IN HUNGARY

There are many regions (19 counties) in Hungary, which are favorable for maize cultivation. However, due to some abiotic (e.g. relief), biotic (e.g. areas for habitat development of different protected birds or mammals) and socio-economic (implementation of agri-environmental programs) factors in some counties maize remained the number one crop, while in other counties production of other crops became favored by farmers.
In this study, we will focus on two counties

- Tolna County (Region 1),
- Bekes County (Region 2)

which are favorable for maize cultivation.

However due to above mentioned factors and due to implementation of different AEP programs (Fig.1. and Fig 2.), different maize based cropping systems were developed in these counties.

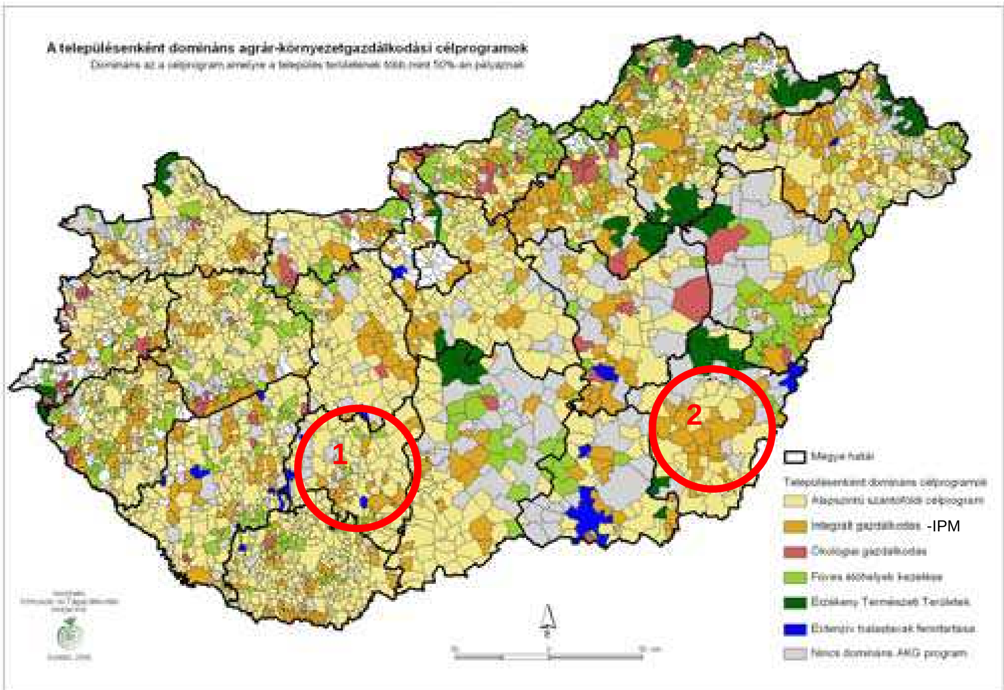

Fig 1.: Dominant Agri-Environmental Programs on Community level (Schneller et al., 2007)
*conventional crop production is not indicated

Characteristics of crop (maize) production in Tolna County (Region 1)

Land use details in Tolna County:

• area of land in km^2	3 704
• area of arable land in km^2	2 600
• area of maize in km^2	1 400
• area of continuous maize in km^2	785

The region is highly favorable for maize production. Maize is cultivated on 55% of a total arable land of the county. Of the total maize acreages continuous maize production makes up about 60%. In many years highest maize yields per hectare has been reached in this county. Farmers may reach 9-10 t/ha grain maize yield in an average year while 10-12 t/ha can also be achieved if the amount of rainfall is high enough. Winter wheat yields are at a range of 4-6 t/ha in this county. Maize is the most economic crop here therefore alternative crops (winter wheat, sunflower, oilseed rape) are not competitive enough.

Characteristics of crop (maize) production in Bekes County (Region 2)

Land use details in Békés county

• area of land in km^2	5 632
• area of arable land in km^2	3 913
• area of maize in km^2	502
• area of continuous maize in km^2	93

Region is suitable for arable crop production. Maize is cultivated on about 13% of the total arable land of the county. Continuous maize makes up about 15% of the total maize area.
Maize was cultivated on large share of the country (more than 50% of arable land) in the past. However after the detection of *Diabrotica virgifera virgifera* (western corn rootworm-WCR) in 1996 and after experiencing significant damages caused by larvae first in 2002, maize production area has been decreased. When AEP programs were introduced in 2004, significant number of farmers joined these programs. Even though maize was (is) the most economic crop in the region, introduction of alternative crops into the rotation system was considered as to economically acceptable due to compensations from these programs.

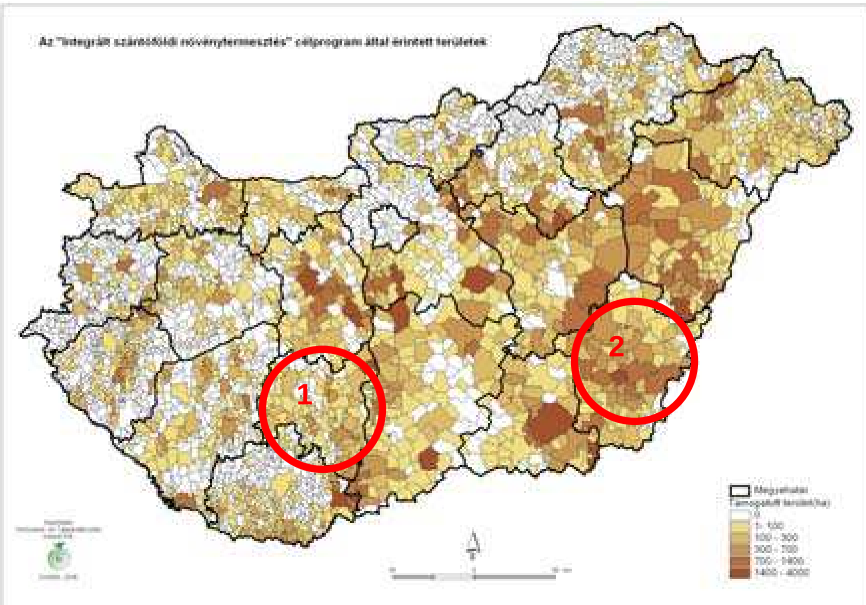

Fig 2.: Areas in Integrated crop production for arable crops (Schneller et al., 2007)

Almost all arable crops, thus maize as well are not irrigated. Value added crops (sweet maize, seed maize, field vegetables) may be irrigated but for the entire Hungary, MBCSs could be described as NON-IRRIGATED, GRAIN maize. The difference in the "two MBCSs" in our analysis is the rotation or continuous cultivation. (Practically, in our comparison, MBCSs with high share of continuous maize and low share of continuous maize (thus typically rotated) was considered. The rotation, thus crop sequence over years and space is the corner stone of pest, disease and weed management in IPM and also has significant economic impact (farmers' income).

ECONOMIC DESCRIPTION OF MBCSs

Grain maize is considered as the most profitable arable crop in Hungary. Price of maize varied from year to year and somewhat from region to region. In the past, in Tolna County the price of the maize was higher compared to Bekes County. The reason for this was that transportation of maize was easy on river Danube. However, after EU accession of Romania, Romanian traders appeared in Bekes County. In years when there was no enough maize in Romania, traders offered higher prices, than in counties far from the border. Due to these phenomena, the actual price of maize in Bekes county very much depends on the maize yield harvested in Romania. Price of the maize is fluctuating year by year, and farmers often could not follow the forces effecting maize price, and they felt that it was not regulated and balanced by demand and supply. Prediction of prices, thus longer term planning by farmers is almost impossible, however main expectations and experiences (the price of the maize is the highest among arable crops) and subsidies effects farmers decision what to cultivate.

Farmers sell their maize grain products the traders or very frequently immediately on the field or to integrator, who appears on the market with bigger amount of product. In the first case there is no contract in the beginning of the season, while in the second case (in most of the cases) the price is fixed early in the season.

DETAILS FOR EXPERT BASED SURVEY (EBS)

The MBCS Core Team developed a template for the Expert Based Survey (EBS) where different preventive, mechanical, cultural and chemical measures were included. Template was filled in by SzIE people based on personal discussions with advisors and farmers in two regions and based on the experiences gained from previous projects (FAO GTFS/RER/017/ITA project IPM for WCR; FP6 2004 – SSP4 – 022623 project-DiabrAct-Harmonise the strategies for fighting *Diabrotica virgifera virgifera*) and from Maize Case Study of ENDURE Project.

RESULTS FROM EXPERT BASED SURVEY (EBS)
MBCSs OF TOLNA AND BEKES COUNTY (Region 1 and Region 2)

Experiences from previous projects indicated that there are two different maize based cropping systems in two regions. Maize is cultivated continuously without irrigation (MS8-Grain maize continuous and non irrigated) in Tolna county, while in rotation without irrigation (MS6-Grain maize rotated and non irrigated) in Bekes county. Advisors and farmers gave information on pests, diseases, weed problems and management.

PESTS, DISEASES AND WEED PROBLEMS OF MBCS IN TOLNA AND BEKES COUNTY

In general weeds cause the greatest problem in maize production, while diseases have the lowest effect. Due to different cropping system some differences were identified regarding importance of different weeds, pests and diseases.

Weeds: *Echinochloa crus galli, Sorghum halepense, Ambrosia elatior* and *Setaria viridis* are the most important crops in both regions. Other weeds are significant in one region such as *Panicum milliaceum* in Tolna County while *Amaranthus retroflexus, Chenopodium album, Cirsium sp. (arvense), Datura estramonium* and *Xanthium sp.* in Bekes County. *Abutilon teophastri* causes problem only in Tolna County, and has almost no importance in Bekes.

Pests: *Diabrotica virgifera virgifera* and *Ostrinia* nubilalis are the main pests of the maize in both regions. In some years, when conditions are favourable population of *Helicoverpa armigera* can reach extremely high level and *Agriotes spp.* (wireworms) can cause damage of economic importance as well. *Tanymecus* dilaticollis can have as big importance as *Diabrotica* in some years and some fields in Tolna County.

Diseases: *Fusarium* spp. related diseases are more frequent in Bekes county where rotation of winter wheat to maize is quite frequent. Other way around (rotation of maize to winter wheat is rear, since harvest of the maize is mainly in the time of sowing the winter wheat). Other diseases such as *Ustilago maydis, Sclerophthora macrospora, Puccinia sorghi* may appear but their economic importance is generally low.

CURRENT AND ADVANCED PRACTICES OF THE MBCSs IN TOLNA AND BEKES COUNTIES

Practices for weed management of major importance are herbicide treatment, crop rotation, tillage and inter row mechanical weed control. Inter row mechanical weeding is frequently used in both regions, since this practice is known as good practice against weeds, maintaining maize crop standing (at certain *Diabrotica* larval damage) by ridging, while on the other hand has positive effect on soil physical structure. Against perennial weeds, herbicide treatment in the stable of previous crop (mainly winter wheat) has the major importance.

Removal of crop residues or ploughing down the maize stalks is the practices mainly used in both regions against European corn borer (*Ostrinia nubilalis*) larvae. Insecticide application is more frequent in Tolna County (20 % of total maize area), while in Bekes County insecticide application against ECB is occasional. Choosing hybrids tolerant for ECB has minor importance in managing of the pest.

Against WCR, the use of crop rotation has major importance in Bekes County, while insecticide treatment (seed coating and/or soil insecticide application) in Tolna County. Nevertheless, we have to indicate, that in Tolna County soil insecticide application against larvae is often based on risk estimation. Risk estimation has to be done by observing WCR adult population in a maize field with traps (Pherocon AM) or with visual count in previous year. Based on the level of the adult population, the expected risk of the larval damage in subsequent year maize field could be estimated. Ridging, fertilization, foliar insecticide applications are considered as practices of minor importance in both regions.

Against other pests (*Agriotes, Tanymecus dilaticollis*) mainly insecticide application (seed dressing) is used on fields supposed to be damaged later by these pests. Against *Helicoverpa armigera* (ear feeding larvae) foliar insecticide application are mainly used in years of high pest population level. Biological control (*Trichogramma* capsules) are applied against *Helicoverpa armigera* on very limited area, mostly in sweet maize cultivation.

Against soil born *Fusarium* spp. related diseases seed treatment is the first management option. Tillage (ploughing), tolerant hybrids are the management options with major importance.

PESTICIDE APPLICATIONS IN TOLNA AND BEKES COUNTY

The highest amount of pesticides is used against weeds, thus herbicide application is the most significant in both regions. Almost 100 % of the maize fields are treated by herbicides. There is no significant difference in application of herbicides between two regions. Average number of herbicide application is 1,3-1,5 application/maize growing season. Mainly post emergence herbicide applications are used (1-1,1 application /season), but pre-emergence applications are also important (0,3 application/season). The following active ingredients are mainly used in both regions: nikosulfuron, dicamba, bentazon, 2,4 D, acetochlor, izoxaflutol, terbutilazin.

There is a regional difference in terms of strategy of insecticide application against western corn rootworm (WCR, *Diabrotica v.v.*). In Tolna County where insecticide application is focusing at first against larval damage, active ingredients used, are as follows: carbofuran, thiamethoxam, tefluthrin, terbufos, imidacloprid and clothianidin. For foliar application against WCR adults, insecticides with lambda-cihalotrin, chlorpirifos, esfenvalerate, and acetamiprid active ingredients are used. In foliar insecticide application, so called Invite technology, where 10% of active ingredient (chlorpirifos) is applied with “feeding arrestant” compound (cucurbitacin). In this technology reduced rate of insecticide active ingredient is used.

Fungicide seed coating of maize is obligatory in Hungary, thus 100 % of the fields are treated against soil born *Fusarium* spp. The most common active ingredients are fludioxinil + mefenoxam and karboxin+tiram.

SWOT ANALYSIS OF MAIZE BASED SYSTEMS
For SWOT analyses maize based cropping systems of two regions, thus:

- continuous non irrigated grain maize (MS8) and
- rotated non irrigated grain maize (MS6) cultivation were compared.

Strengths of MS8 (**non rotated**) system from technical viewpoint are, that it is a very simple system, relaying on the cultivation of one main crop (maize) with limited rotation with few other crop stands (winter wheat, oilseed rape, sunflower). Due to this simplicity, farmers knowledge is very deep on crop cultivation and they can easily manage maize systems with their (mainly owned) equipment and experience. Environmental conditions, such as soil and climate conditions are ideal for maize production, thus maize yields are higher in this region compared with many others in Hungary. Thus other strength of MS8 in Tolna County is the higher yield of maize, thus higher income.

Strength of other system (MS6 –**rotated maize**) can be summarized in word “balanced”. Due to higher diversity of crops in the system, inputs and incomes are more balanced over time. From environmental viewpoint diversity of cultivated crops in time and space lead to less insecticide application and thus less environmental load. On the other hand, green manure production in AEP programs gives added value for environment (habitat for natural enemies, better soil conditions). In this system, the prevention of pest and diseases population built up is better, and weed management could be more properly done by mechanical weed control on stables of cereals, or by herbicide treatments against perennial weeds of maize (e.g. *Sorghum*). Appearance of *Fusarium* mycotoxins is also lower, if maize is rotated with dicotyledonous species. From economic viewpoint, farmers are less market dependant (over time) and they can choose cheaper control options (e.g. they have more possibility to choose when to use and what kind of control option from IPM tools). Subsidy for AEP programs is also strength of this system.

Weaknesses of continuous maize production from technical viewpoint are, that there are time peaks in work, thus timing of management options are not always optimal. On the other hand, since farmers have great knowledge and experience in maize cultivation they are less open minded for technical changes in their system. Since maize production is very intensive, appearance of some pest (WCR, ECB) and diseases (*Fusarium* spp.) in continuous maize production is more likely. To manage these pests and to enhance the crop higher pesticide and fertiliser inputs are used, thus environmental load is higher in this system. Consequence of single commodity, thus fluctuation of yield and market prices over time is an economical based weakness of the system.

Weaknesses of system with rotation, more equipment is required to be able to manage different crop stands, thus more technical investments are needed. On the other hand, beside the technical investment more time and energy investment is needed to gain broader knowledge in cultivation of different crops. In the region with maize rotation system, the other main crop is winter wheat. Rotation of winter wheat to maize is very frequent, thus appearance of *Fusarium* spp. and *Fusarium* mycotoxins in maize is more likely.

Opportunities for system with continuous maize production are that it can rely on single innovation method. From environmental viewpoint biological control options and reduced active ingredient rate could be used based during cultivation of a single crop. Furthermore, this system could be fine-tuned by risk estimation.

Opportunities for system with rotation are, that it could rely on system functioning, thus less intervention is needed. With involvement of new crops, the system could become more balanced from economical and environmental viewpoint as well. Broadening farm functions (e.g. village tourism), producing value added products are also among the opportunities of this system. For both regions opportunities are to use more advanced practices and linked with this to have training for capacity and knowledge development of farmers.

Threats: Population build-up of pests and diseases, development of herbicide resistance and probability of mycotoxins are major threats in the **continuous maize systems**. On the other hand this system can not cope with new requirements (neither environmental, nor economic), and even it would be ready to change inertia of the system is very high. The system is very much exposed to market conditions, thus profitability is also a question.

System with rotation, which very much relies on the subsidies and support policy for Agri-Environmental Programs is exposed to policy changes. With focusing only on subsidies, system can loose its connection to market driven production. Food and feed safety concerns as well as high input prices are the common threats identified in both groups of systems.

In conclusion, for MBCS in continuous production agronomical, technical while for MBCS in rotation environmental strengths) were identified. From social viewpoint MBCS in rotation has significantly greater opportunity in them of farmers capacity development and in terms of producing added values for the society as well.

CONSTRAINS, CHALLENGES FOR FUTURE DEVELOPMENT

Both systems offer a good chance for implementation of new, advanced and innovative technologies to manage technical weaknesses and threats of a given system. In link with that, training and capacity development of farmers is a big challenge and chance as well. In parallel with this, challenges in policy development also appear regardless on cropping systems. Economic constrains are that subsidies and market driven forces effect against each other at some level. Balance of these forces has to be found at each cropping system by policy makers. Acceptance of some new technologies by society (e.g. GMO crops) and approval of these crops for cultivation is a social, economic and environmental challenge as well.

We should note that above analysis is based on national regulatory, farming and cultivation conditions being valid in the first AEPs period (2004-2009). In these programs, for integrated arable production, rotation of crops was obligatory, which will not be the case (in this simple way) for the next AEPs period. Farmers response to a somewhat more flexible approach in the latter AEPs, IPM/IP/IF practices adopted by farmers, commodity prices and overall market conditions for arable crops harvested is a challenge.

In addition to this, the forthcoming obligatory national IPM regulations under EU Pesticide Framework, global challenges for farmers (competition on market), “new” opportunities for crop cultivation purposes (biogas, etc.) and expected changes in subsidies from 2014 will be of high importance. Developing new, innovative tools to be applied in IPM by farmers, their capacity development to address the new challenges are to our view of crucial importance.

Literature:

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3.2. SWOT analysis of MBCS in the selected region in Italy

Po Valley region, Italy
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INTRODUCTION

The region of Po valley is located in the north of Italy (NUT region: 1) and is characterised by a mild continental climate (Appendix, Figure 1). The average temperature is 17 ℃ and the average precipitation from April to October is 380 mm. It is the major Italian agricultural region for maize production as 1,200,000 hectare out of total maize area of Italy (1,300,000 ha) is located in this region. The proportion of total maize area grown here with grain maize is 75%, while 24% is grown with silage maize. The remaining 1% of is dedicated to seed production, sweet maize or bio-fuel. Currently, 80% of total maize area is under conventional maize cultivation and the remaining 20% is grown under IPM guidelines. In terms of ownership and management, there are many small full or part time farmers who are mostly depending on contractors for managing their fields.

SOCIO-ECONOMIC DESCRIPTION OF MBCS

The Italian market of grain maize is related to that of the commodities at European level, or even at global level, and price is fluctuating accordingly, making the prediction of future price rather difficult (subsidies are always important) and preparing longer term plans is quite impossible. Theoretically, Italian farmers have full access to market, given that the delivery of grain is not restricted. In practice, farmers in a certain area rely especially on dealers acting in the same area; furthermore, often the decision for the final destination of the maize product is made by the contractors.

DETAILS FOR EXPERT BASED SURVEY

The MBCS Core Team developed a template for the Expert Based Survey where different preventive, mechanical, cultural and chemical measures were included. For Italy, the experts were asked to provide information on typical maize based cropping systems of Po valley, focusing on key pest and disease problems and state the current or the possible advanced practices and their importance for each maize based system. This was done by regarding region as a flexible spatial unit in order to allow focusing on key plant protection issues mentioned. For this survey, experts from agrochemical companies, extension services, academic institutes and agrochemical dealers were asked to contribute for Po valley (Appendix, Table 1). The choice of experts, based in different parts of the Po valley, resulted in a wide and complete understanding of the current situation in this region. All information obtained were then integrated and summarized.

RESULTS FROM EXPERT BASED SURVEY
MBCSs OF THE PO VALLEY

The expert based survey identified five maize based cropping systems in the Po valley. The main system is the grain maize rotated and irrigated (MS5), which is common in the centre, centre-west, west, north-east and south-east of the Po valley. Further significant systems include the silage maize rotated and irrigated (MS1) and the grain maize continuous and irrigated (MS7) identified in the centre, west and north-east of the Po valley. Other minor systems were the silage maize continuous and irrigated (MS3) in the centre (main production area of the Grana Padano cheese) and the grain maize rotated with no irrigation (MS6) in the north-east of Po valley (Appendix, Table 2), where the annual rainfall often exceeds 1,500 mm.

In terms of proportion (%) of area covered by the maize based systems, the grain and silage maize under rotation and irrigation (MS5 & MS1) covers about 50% of the Po valley arable land and approximately 570,000 ha, whereas the continuous grain and silage maize

under irrigation (MS7 & MS3) an area of 30% of the Po valley and approximately 340,000 ha. Finally, the grain maize under rotation and without irrigation (MS6) was found to cover 20% of Po valley and approximately 230,000 (ha).

PESTS, DISEASES AND WEEDS IN MBCS IN THE PO VALLEY

The same troublesome weeds, pests and diseases were identified by the expert survey in all maize based systems in the Po valley. *Fusarium* spp. related diseases (ear, stalk and root rot) were indicated to have the highest economic impact. In terms of arthropods, the most important problem is the European corn borer (ECB, *Ostrinia nubilalis*), with western corn rootworm (WCR, *Diabrotica virgifera virgifera*), wireworms (*Agriotes* spp.) and cutworms (*Agrotis* spp.) following in relation of economical importance. It should be noted that since the first detection of WCR in Italy, the most serious maize plant lodgings due to larval damage of WCR were experienced in summer of 2009 and subsequent yield losses are expected upon harvest. Some estimates reach 1 million tonne maize grain loss for 2009.

Weeds of major importance include perennial species like *Sorghum halepense*, *Convolvulus arvensis*, *Cynodon dactylon* and annual weed species like *Abutilon theophrasti*, *Amaranthus retroflexus*, *Chenopodium album* and *Echinochloa crus-galli*.

CURRENT AND ADVANCED PRACTICES OF THE MBCS IN THE PO VALLEY

The current practices against the main weeds, pests and diseases of the MBCS were also listed by the experts. Against *Fusarium* spp. related diseases, major tillage (ploughing), removal of crop residues, crop choice in rotation (for systems in rotation), variety choice (for maize) and early sowing were indicated as current practices of major importance, whereas plant nutrition and seeds treated with fungicide of minor importance (Appendix, Table 3). Early detection, major tillage (ploughing), removal of crop residues, early sowing and insecticide application are the practices of major importance against the European corn borer, while minor tillage (e.g. harrowing), crop choice in rotation (for systems in rotation) and plant nutrition were considered as practices of minor importance (Appendix, Table 4). Similarly, early detection, major tillage (ploughing), crop choice in rotation (for systems in rotation) and insecticide application were identified as the most important practices against the western corn rootworm, while early sowing and seeds treated with insecticides were considered as practices of minor importance (Appendix, Table 5). Minor tillage, crop choice in rotation (for systems in rotation) and insecticide treatments in granular form along the row are currently used against wireworms. Major tillage and insecticide application were considered as less important practices against wireworms and cutworms (Appendix, Table 6). Practices of major importance for weed management include tillage, early detection and herbicide application, whereas interrow cultivation, crop choice in rotation (for systems in rotation) and cleaning of harvester were determined as current practices of minor importance (Appendix, Table 7).

The expert based survey provided also candidate advanced practices that might be used in the near future. Experts consider that early detection of *Fusarium* spp., wireworms and cutworms is an advanced option of great importance, especially for *Fusarium* spp. related diseases in relation to mycotoxin production. Choice of maize variety against the European corn borer, western corn rootworm, wireworms and cutworms is believed to be another advanced practice of importance. Field margin management against European corn borer, western corn rootworm (e.g. enhancing their natural enemies in the surrounding landscape) and weeds (e.g. mowing, herbicide application) can be also an important part of an advanced maize based system. After the suspension of neonicotinoids in Italy (Bonazzi, 2009) experts believe that efficient alternatives for seed dressing are needed against western corn rootworm, wireworms and cutworms. Finally, varieties/crops resistant to *Fusarium* spp., European corn borer, western corn rootworm and to specific herbicides can be the advanced solutions to most problems of the MBCS of the Po valley.

PESTICIDE USE IN THE PO VALLEY

Pesticide applications (including seed treatments) are the most common practices for pest and disease management. The highest pesticide load comes from herbicide applications, which is estimated to be practiced in 96% of the total maize area. Different strategies are used: only pre-emergence (52% of total maize area treated), only post-emergence (7,5%) or pre and post-emergence (40%) applications using full dosage in all cases. Active ingredients include acetochlor and isoxaflutole for pre-emergence, fluroxypyr, nicosulfuron (and other sulfonylureas), s-metolachlor and terbuthylazine for post-emergence, dicamba and mesotrione for pre or post-emergence treatments. Herbicides applied in pre-emergence, i.e. in bare soil, are more likely to reach surface water, while in post-emergence application soil is covered by crop and weeds and this risk is reduced. However, post-emergence applications have the highest environmental load, especially due to sulfonylureas which have a high eco-toxicity and mobility with a great risk to reach water.

In terms of insecticides, seeds dressed with insecticides is the main practice against western corn rootworm, wireworms and cutworms (80% of total maize area treated – before the suspension) in the region, whereas, mainly against European corn borer, one application of spray insecticides or on-plant microgranules (11% of area) is practiced when needed. The most commonly used active ingredients in spray insecticides are lambda cyhalothrin, alphamethrin, chlorpyrifos, cypermethrin, deltamethrin.

Against *Fusarium* spp. related diseases, all seeds are treated with fungicides in the Po valley region. The most common active ingredients are fludioxinil, metalaxil-m and prochloraz.

IMPORTANCE OF CROP ROTATION FOR CONTROLLING PESTS AND DISEASES OF THE MBCS

By its nature, crop rotation is a practice that brings into the system different crops (as host plant or food source of pests and diseases), crop planting dates and growth periods, tillage practices, life cycles, competitive characteristics and pesticide applications to prevent the build-up of adapted weeds, pests and diseases. In MBCS, introducing dicotyledonous crop species into rotation with maize will result in a lower *Fusarium* spp. survival and likely a lower mycotoxin production. Crop rotation is also highly effective against the western corn rootworm, as female adults lay their eggs mainly in maize fields, the eggs hatch in the following year and the larvae can not feed if no maize roots are present. Against wireworms, rotating maize with crops that create an inhospitable soil environment is an option. Alfalfa is a good example as it serves as a soil-drying crop and very low soil moisture content can reduce wireworm densities. Finally, rotating maize with dicotyledonous crops or winter wheat will allow the use of a wider range of herbicides with different modes of action, including non-selective a.i., so minimising the risk of herbicide resistance. A few populations of *Echinochloa crus-galli* resistant to sulfunylureas have been recently found in continuous maize cropping systems.

WEEDS, PESTS AND DISEASES OF CROPS IN ROTATION WITH MAIZE

When maize is rotated with other crops, such as winter wheat or barley, soybean, oilseed rape and other crops, only a relative small number of weeds, pests and diseases become dominant.

When maize is steady rotated with winter wheat or barley, an increasing incidence of *Fusarium* spp. related diseases is expected, although the weather plays also an important role. An increasing wireworms (*Agriotes* spp.) population density is expected when maize is planted after meadow. Weed problems are never increased by crop rotation, but is exactly the opposite given that specific herbicides effective against grasses can be used in other crops.

In relation to the environmental impact, it has to be noted that in maize a large amount of nitrogen fertilisers is used (200 or more kg/year) in 1-3 application, but also that the yield is very high, and nitrogen loss is therefore likely to be not high. Carry-over effects of

herbicides, either applied on maize or in rotated crops, are not observed when standard agricultural practices are used.
In general, the adoption of a proper rotation (or even of a simple crop sequence) helps in managing pests by breaking the pest reproductive cycles and in the reduction of pesticide build-up in the environment. In fact, rotations that increase organic matter improve the biological activity and therefore the breakdown of pesticides. However, the use of pesticides remains the key and standard practice in most cropping systems.

SWOT ANALYSIS OF MAIZE BASED SYSTEMS
For the SWOT analysis two groups of systems were formed, based on type of cropping sequence (continuous maize and maize-based rotation), as not important differences exist between grain and silage maize systems in the Po valley. The first group included silage and grain rotated, with (MS1-MS5) or without irrigation (MS6) and the second group silage and grain continuous with irrigation (MS3-MS7).

Strengths of agronomical importance were determined in the ”rotated” group in terms of better nitrogen availability, soil structure, water stress effect in maize, prevention of pest and disease build-up, weed control when crop is not cultivated and better herbicide resistance management. Other strengths in the first group of systems include the availability of infrastructures for irrigation (for MS1, MS5) and contractors that easily manage maize systems with their equipment and experience. In relation to economical strengths, maize in rotation with other crops likely results in higher maize yields than in continuous maize systems. Finally another strength of great importance is the low potential of mycotoxins when dicotyledonous species are included in the rotation.

For the second group of systems the most significant strength is that maize can take advantage of the often ideal climatic conditions, plus available infrastructures for irrigation, the fact that farmers are familiar with the maize production or experienced contractors that can manage maize systems with proper equipment. However, the existence of a market and the demand for maize productions (grain or silage) is the driving force of these systems (Appendix, Tables 8-9).

Economically based weaknesses were identified in the first group, which included the cost of equipment needed for the different crops in rotation. Further weaknesses involved the potential of *Fusarium* spp. survival and mycotoxins when maize is rotated with wheat, the low biodiversity when warm-season crops are rotated and potential water stressed maize in the maize system without irrigation (MS6).

In continuous maize systems there is a general intensification of agriculture and higher environmental impacts due to high pesticide and fertiliser inputs. Other weaknesses include soil compaction or erosion, nitrogen leaching and efficient residue management that is needed to prevent certain pests and diseases of continuous maize systems. Fluctuating market price for maize can also be considered as an economical based weakness of the systems.

The same opportunities were determined for both groups of systems. These included the availability of more advanced practices, IPM maize production, biological and pheromone-based monitoring and control options and new technologies (Bt maize, new hybrids and decision support systems). In order to take into consideration these opportunities financial support to farmers to obtain or adjust equipment for actual implementation of the advanced practices mentioned and information and training by the regional agricultural extension services is essential. Finally, in terms of economically based opportunities, price stabilisation for maize (for continuous maize systems) and crops in rotation was considered to be a good opportunity for overcoming certain economical constrains of the systems.

Environmental and food safety concerns and not stable fuel prices are the common threats identified in both groups of systems, whereas build-up of pests and diseases, development of herbicide resistance and probability of mycotoxins are threats of major importance in the continuous maize systems.

In conclusion, for MBCS in rotation, agronomical, environmental, and economical strengths, and more economical based weaknesses were observed, whereas economical strengths, and more agronomical and environmental based weaknesses were identified in the second group. For both groups, the same opportunities were determined, however more threats were identified in MBCS with continuous maize.

CONSTRAINS, CHALLENGES FOR FUTURE DEVELOPMENT

The major constrains for the development of **advanced** and **innovative** MBCS include challenges in terms of:

- availability of resources,
- economics,
- knowledge,
- and education.

In order to consider the introduction of an advanced or innovative practice the new machinery, working products, or suitable maize cultivars should be available for the farmers to purchase. Some examples that were mentioned also from the Maize Case Study group include new machinery for mechanical weed control, *Trichogramma* parasitoid as a product for European corn borer biological control, and cultivars with resistance to *Fusarium* spp. diseases which are already available in the market. However, other innovative practices like precision spraying, or pheromone-based pest forecast and control against multiple pests of MBCS still need further research and hence they are not available. Moreover, the introduction of Bt maize resistant to European corn borer (indirect consequence is a reduced mycotoxin level in grain), Western Corn Rootworm resistant Bt maize, herbicide tolerant GM maize is not allowed by law in certain countries (e.g. Italy) and therefore this new technology is not yet available for farmers.

Furthermore, in order to make an advanced or innovative practice attractive to farmers or suppliers they need to be followed with a rational cost as otherwise they will not be considered in the toolbox of pest control practices for MBCS. This economic constrains can be overcome if subsidies are available to farmers to buy new equipment, technologies or pest control products in order to make these new strategies a sustainable option with longer term benefits and which are economically competitive with current strategies.

Knowledge and education of the operators on how to use efficiently these advanced or innovative practices is essential in order MBCS to benefit from these strategies. The development of a close link between research, companies, consultants, contractors and farmers can be the key to this constrain. This can be done with farmers and contractors participation in field trials experimenting on these new strategies, IPM training by agricultural extension services, open days of agricultural companies or research institutes, private or company advisors and journal or leaflet distribution.

SUGGESTIONS FOR DEVELOPING IPM IN MBCS

The presence of several problems that need to be confronted at the same time raises the need for IPM approaches, which integrate the most efficient environmentally friendly methods to maintain the ecological balance of the crop production system. In terms of this necessity, this study revealed certain advanced practices already available, which could be included in an advanced IPM strategy for MBCS immediately, and some innovative suggestions on practices that could be included in an innovative IPM scenario in the near future. The advanced practices that can be used in MBCS of the Po valley include: (1) efficient choice of hybrids (drought, disease tolerant), (2) optimisation of herbicide

applications timing for efficient weed control and better use of interrow cultivation, (3) fertiliser band application and narrow spacing to provide competitive advantage of maize over weeds, (4) biological control (*Trichogramma* spp. against ECB) and (5) pheromone-based monitoring and control (wireworms, cutworms, WCR and ECB). Possible innovative suggestions for the near future involve the use of Bt maize resistant to ECB, WCR, or with herbicide tolerance, precision spraying, improved Decision Support Systems and forecast systems (pest, diseases and weeds monitoring). All these advanced and innovative solutions will result in more environmentally sustainable MBCS in the Po valley.

However, in order to consider these solutions subsidies to farmers are needed for certain of the advanced solutions proposed (i.e. buy or adjust equipment), whereas permission of the use of GM maize should be established by law. Finally, information and training of the farmers and contractors on the new tools available is vital for more efficient and sustainable IPM in MBCS in the Po valley.

References

Bonazzi, M.C. 2009. Italy keeps ban on neonicotinoid seed coating to save bees. Available from: http://www.youris.com/Environment/Bees/Italy_keeps_ban_on_neonicotinoid_seed_coating_to_save_bees.kl (accessed 20 July 2009).

Appendix

Figure 1. Po valley, Italy

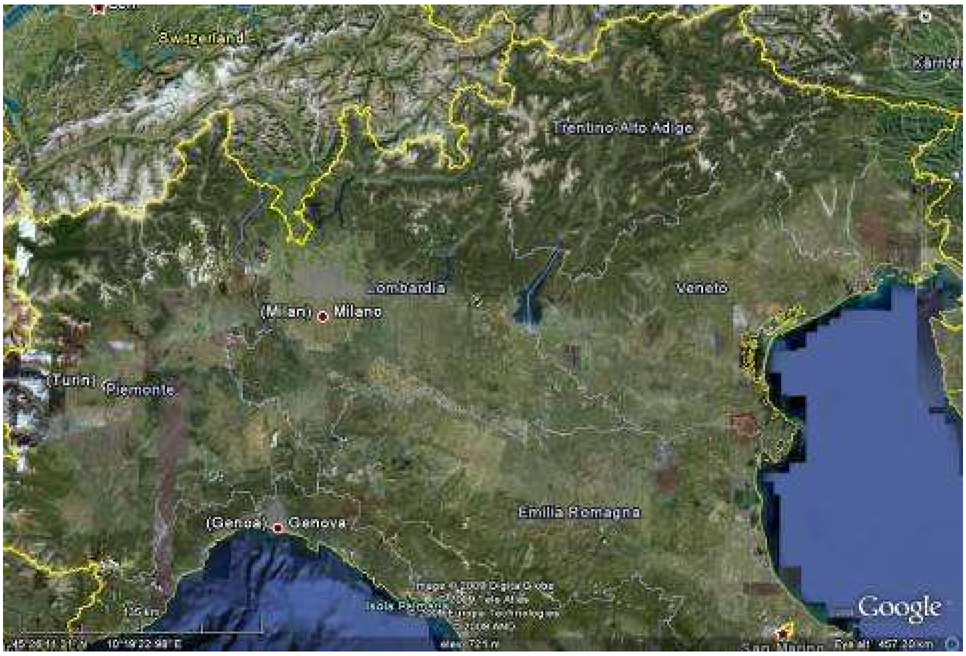

Table 1. Experts list

Name	Institution
G. Casari	DuPont
C. Campagna	Syngenta
G. Governatori	Extension service (Friuli-Venezia Giulia)
M. Agosti	Extension service (Brescia)
P. Meriggi	Horta Srl (University of Piacenza)
L. Giardini	University of Padova
L. Furlan	University of Padova
A. Ferrero	University of Torino
F. Merlo	Cereals and Agrochemical dealer (Padova)

Table 2. Description of 8 main Maize Based Systems

MS1	Silage maize in rotation irrigated
MS2	Silage maize in rotation not irrigated
MS3	Silage maize not in rotation irrigated
MS4	Silage maize not in rotation not irrigated
MS5	Grain maize in rotation irrigated
MS6	Grain maize in rotation not irrigated
MS7	Grain maize not in rotation irrigated
MS8	Grain maize not in rotation and not irrigated

Table 3. Current and advanced practices against *Fusarium* spp. related diseases in the different maize based systems of Po valley, Italy

Practices	**MS1-MS5**	**MS3-MS7**	**MS6**
Removal of crop residues	X		
Early detection	**x**		
Major tillage (ploughing)	X		
Crop resistance	**X**		
Crop choice in rotation	X		
Variety choice	X	X	X
Early sowing	X	X	X
Plant nutrition	x	x	X
Fungicides	x	x	X
Seed treatments	x	X	X

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance

Table 4. Current and advanced practices against European corn borer (*O. nubilalis*) in the different maize based systems of Po valley, Italy

Practices	**MS1-MS5**	**MS3-MS7**	**MS6**
Removal of crop residues	X		
Field margin management	**x**		X
Early detection	X		
Major tillage (ploughing)	X	X	X
Minor tillage (harrowing etc.)		x	X
Crop resistance	**X**	**X**	
Crop choice in rotation	x		X
Variety choice	**X**	X	
Early sowing	X	X	X
Plant nutrition		x	
Insecticides	X	X	X

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance

Table 5. Current and advanced practices against western corn rootworm (*D. v. virgifera*) in the different maize based systems of Po valley, Italy

Practices	MS1-MS5	MS3-MS7	MS6
Field margin management	x		
Early detection	X		
Major tillage (ploughing)	X		
Crop resistance	x	x	
Crop choice in rotation	x		X
Variety choice	x		
Early sowing	x	x	X
Insecticides	X	X	X
Seed treatments	x	x	X

x, X = current practice of minor or major importance
x, **X** = advanced practice of minor or major importance

Table 6. Current and advanced practices against wireworms (*Agriotes* spp.) and cutworms (*Agrotis* spp.) in the different maize based systems of Po valley, Italy

Practices	MS1-MS5	MS3-MS7	MS6
Early detection	X	X	X
Major tillage (ploughing)		x (wireworms)	X (wireworms)
Minor tillage (harrowing etc.)			X (wireworms)
Crop choice in rotation	x		X (wireworms)
Variety choice	X		
Insecticides	x	x	X
Seed treatments	X	X	X

x, X = current practice of minor or major importance
x, **X** = advanced practice of minor or major importance

Table 7. Current and advanced practices against major weeds in the different maize based systems of Po valley, Italy

Practices	**MS1-MS5**	**MS3-MS7**	**MS6**
False seedbed	X	**x**	
Field margin management	**x**	X	X
Early detection	X	X	
Major tillage (ploughing)	X	X	X
Minor tillage (harrowing etc.)	X	X	X
Interow cultivation	x	x	
Crop resistance	**x**	**x**	
Cleaning of harvester	x	x	x
Crop choice in rotation	x	x	
Herbicides	X	X	X

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance

Table 8. SWOT analysis of MBCS in the Po valley rotated, with (MS1-MS5) or without (MS6) irrigation

Strengths	
• Higher maize yields than in continuous maize systems	• No herbicide resistance (herbicides with different modes of action used)
• Control of annual and perennial weed species when crop not cultivated	• Rotation between deep-rooted and shallow-rooted crops improves soil structure
• Low potential of mycotoxin when rotating with broadleaved species	• Available infrastructure for irrigation (MS1-MS5)
• Soybean in rotation provides nitrogen for following crop	• No or low 'water stress' effect on maize (MS1-MS5)
• Prevention of pest and disease build-up	• Contractors (experience and equipment available)
Weaknesses	
• Fluctuating market prices for different crops in rotation	• Potential for 'water stress effect' on maize (MS6)
• Low diversity of crops when warm season crops in rotation (e.g. maize-soybean)	• Cost of different types of equipment needed for crops in the rotation
Opportunities	
• Price stabilization	• Choice of hybrids (yield, drought, disease tolerance)
• Bt maize	• Biological control (e.g. *Trichogramma*)
• Minimisation of pesticide use through IPM maize production (currently 20% of total maize area)	• Pheromone-based monitoring and control
• Availability of more advanced practices (fertiliser band application, narrow spacing, optimizing timing of herbicide application etc.)	• Forecast and decision support systems
• Information/training by regional agricultural extension services	• Financial support to farmers to buy or adjust equipment
Threats	
• Environmental and food safety concerns	Not stable fuel prices

Table 9. SWOT analysis of MBCS in the Po continuous with irrigation (MS3-MS7)

Strengths	
• Market/Demand	• Farmers familiar with maize production
• Favourable production conditions (climate)	• Availability of water and infrastructure for irrigation
• No or low 'water stress' effect on maize	• Contractors (experience and equipment available)
Weaknesses	
• Intensification of agriculture	• Nitrogen leaching
• Fluctuating price of maize	• High fertilizer inputs
• Soil erosion or compaction	• Residue management needed
• Relatively high pesticide inputs due to build-up of specific pests and diseases	
Opportunities	
• Price stabilization	• Choice of hybrids (yield, drought, disease tolerance)
• Bt maize	• Biological control (e.g. Trichogramma)
• Minimisation of pesticide use through IPM maize production (currently 20% of total maize area)	• Pheromone-based monitoring and control
• Availability of more advanced practices (fertilizer band application, narrow spacing, optimizing timing of herbicide application etc.)	• Forecast and decision support systems
• Information/training by regional agricultural extension services	• Financial support to farmers to buy or adjust equipment
Threats	
• Build-up of specific pests and diseases	• Mycotoxin contamination more probable
• Development of herbicide resistance	• Environmental and food safety concerns
• Not stable fuel prices	

3.3. SWOT analysis of MBCS in selected region in Spain

Ebro Valley region, Spain
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INTRODUCTION

The region of Ebro Valley is located in the Northeast of Spain (NUT region: XX) and it is characterised by a Mediterranean climate. The average temperature from de period April-October is 18ºC and the average precipitation is about 200 mm. It is one of the major Spanish regions in maize surface and production. In the region 100 000 ha are devoted to maize, the 28.6 % of the Spanish maize surface (350 000 ha). Average yield of grain maize is 13 tn/ha and in silage maize is about 30 th of dry matter/ha. Grain maize is 85% of the total maize area whereas silage maize is 15%. Monoculture is 17% of the surface and the 83% is under crop rotation, mainly wheat-maize. Very few hectares are cultivated under IPM guidelines. Maize is only cultivated with irrigation (50% by gravity and 50% by sprinklers). Size of fields is variable with an average of 5 ha. Very high doses of nitrogen are applied.
The Spanish market of maize is related to that of the commodities at European or global level and the price varies every year according to these relationships and in general grain price is quite low. Spanish maize producers have full access to the market. There are dealers (private or cooperatives) that buy, store and sell the maize products to the final destination.

DETAILS FOR EXPERT BASED SURVEY

The experts were asked to provide information on typical maize based cropping systems of Ebro Valley, focusing on key weed, pest and/or disease problems and stated the current or the innovative practices and their importance for each maize based system. This was done by regarding region as a flexible spatial unit in order to allow focusing on key plant protection issues. For this survey, experts from the University of Lleida, Department of Agriculture, extension advisers from private companies, experts from agrochemical companies and significant farmers were asked in order to have a wide overview of the maize crop system in the region (Table 1).

RESULTS FROM THE EXPERT BASED SURVEY
MCBSs OF THE EBRO VALLEY

The expert based survey identified two maize based cropping systems in the Ebro Valley. The main system is the rotated maize that includes grain maize system (MS5) with 68000 ha and silage maize system (MS1) with 15000 ha. The second system was that of maize monoculture (MS7) that includes 17000 ha.

PESTS, DISEASES AND WEEDS IN MBCS IN THE EBRO VALLEY

The same problems of weeds, pests and diseases were identified by the expert survey in the two maize based systems in the Ebro Valley. Insect born viruses were the most significant diseases in the region, especially maize dwarf mosaic virus (MDMV) transmitted by aphids in a non-persistent manner, and maize rough mosaic virus (MRMV) transmitted by planthoppers in a persistent manner. Post-harvest mycotoxins derived from *Fusarium* spp. infections were determined as important.

Corn borers were the arthropod pest with the highest economic impact. In the region two corn borers coexist, the Mediterranean corn borer (MCB, *Sesamia nonagrioides*) and the European corn borer (ECB, *Ostrinia nubilalis*), and damages from the former corn borer being generally most important than those of the later. Cutworms (Agrotis sp.), wireworms (*Agriotes lineatus*) and sup sucking insects (aphids and leafhoppers) are considerated economically secondary pests. Damages of *Mythimna unipuncta* sporadically occurs but can be economically dramatic. Low but increasing occurrence has Helicoverpa armigera. Spider mites (*Tetranychus* sp.) are frequent in fields irrigated by gravity.

Echinochloa cruss-galli, Setaria spp. and *Sorghum halepense* are monocotyledon weeds of the major importance whereas among dicotyledon weeds are *Chenopodium album*, *Amaranthus* sp. and *Abutilon theophastri*.

CURRENT AND ADVANCED PRACTICES OF MBCS IN THE EBRO VALLEY

Seeds treatment is the current practice to prevent maize virus infection and nearly 100% of commercial seeds are dressed with insecticide. The effectiveness of this method is considered low. Crop resistance and management of sowing date (especially when escape to the infective vector is possible) are advanced practices that may be used in the near future (Table 2).

Removal of crop residues, tillage, crop resistance and insecticide sprayings are the major current practices used against corn borers in both maize based system defined. Crop resistance using Bt varieties is the most widely control method currently used in the Ebro Valley (65% of maize surface are cultivated with this varieties). Crop choice and early sowing are minor practices currently used in rotated systems. Advanced practices are similar for both systems. Mating disruption could be an advanced method, especially against MCB, if price of its implementation decreases. The same problematic appears with inundative biological control with *Trichogramma* sp. against ECB. Conservation biological control, field margin management and variety choice are advanced practices also recommended (Table 3). Major tillage and seed treatments are the main current practices against wireworms and cutworms. Experts pointed out that the early detection, crop resistance mainly for cutworms (transgenic plants, for example) may be major advanced practices to be used in both systems (Table 4). Seed insecticide dressing is the only method used to control aphids and leafhoppers. This preventive method is quite effective but many times unnecessary; however, nearly 100% of the commercialized seeds are already dressed with insecticide. Alternative advanced practices listed by experts are filed margin management and conservation and increase of natural enemies (especially for rotated systems), early detection, balanced fertilization (Table 5). Filed margin management and increase and conservation of natural enemies were also indicated as advanced methods to control spider mites (Table 5). Changing gravity irrigation to sprinklers was a proposal to avoid damages of spider mites in rotated maize (Table 5). Fields were maize is cultivated as monoculture are irrigated by sprinklers. Insecticide spraying is the major current control method against *Heliothis* and lepidopteran leaf feeders (*Mythimna*). Crop resistance (transgenic plants for example) and field margins management (in rotated systems) are the two major advanced practices proposed (Table 6).

The current practice of major importance for weed management is herbicide treatment. In rotated maize the crop choice in rotation is also used to reduce the weed impact. False seedbed, delay of sowing and band treatment by herbicides are the advanced practices that experts proposed. Other advanced measures with minor importance are also in Table 7.

PESTICIDE USE IN THE EBRO VALLEY

Pesticide applications are the most common control practices. Practically the totality of fields are treated with herbicides in preemergence and most than 50% in postemergence. In spite 65% of maize surface is sown with Bt varieties, nearly 100% of the seed is dressed with insecticide. In addition, insecticides are sometime applied to control some secondary pests like cutworms or leaf feeders. Maize seeds are also treated with fungicides to ensure nascence but no more fungicides are applied during the growing season.

WEEDS, PESTS AND DISEASES AND IMPORTANCE OF CROP ROTATION FOR CONTROLLING PESTS AND DISEASES OF THE MCBS

Wheat is the crop usually planted in the typical crop rotation with maize. No economic problems with arthropod pests usually occur in wheat in The Ebro Valley. Most of the species of aphids, leafhoppers and planthoppers, cutworms and wireworms may affect winter wheat

and maize. However, only aphids may cause sporadically damages in winter wheat. No significant increases of *Fusarium* in rotated maize with winter wheat have been reported. This type of rotation allows using a wider range of herbicides than in maize monoculture.

In some farms the crop rotation includes alfalfa. Alfalfa bears a very high insect diversity and any of the potential arthropod pests affect maize or winter wheat. On the contrary, the most abundant natural enemies reported in alfalfa also occurs in maize and winter what suggesting that alfalfa is a reservoir of natural enemies and that there is a dymanic population interchange of these natural enemies between crops. Diversification of crop rotation supposes reduction of weed impact in maize and to use wider range of herbicides with different modes of action, minimising the risk of herbicide resistance.
Crop rotation, especially when alfalfa is included, contributes to reduce the nitrogen inputs to the system.

SWOT ANALYSIS OF MAIZE BASED SYSTEMS
Strengths, weaknesses, opportunities and threats were analysed for the two maize based systems described.
Strengths for the both maize systems were determined as high yield, crop resistance technology (Bt maize) adoption and subsequently lower incidence of corn borers and mycotoxins. The specific strengths in rotated maize were the breakdown of pest cycles, a better weed control, availability for enhancing natural enemies, improvement of the fertility and soil structure conditions. The specific strengths for monoculture were that it is a simpler crop system and abetter irrigation technology has been developed. Rotated maize system is not depending only on this crop as in monoculture occurs (Table 8).

The most significant common **weakness** for the two systems was the high quantity of nitrogen applied for fertilization (Table 8). In addition, the not economically use of biological control against ECB and the not existence of an effective alternative to Bt maize for MCB control and the use of preventive insecticide treatments are also common weaknesses for both maize systems. Maize in monoculture is prone to be more affected if the Western Corn Rootworm (*Diabrotica virgifera virgifera*) invades the Ebro Valley. The enhancement of natural enemies is also difficult in maize monoculture, whereas other crops in rotation may be reservoirs of maize viruses (for example, cereals). Not practical forecast systems have been developed in the region.

The good results given by the adoption of Bt maize technology against corn borers makes easier to the farmer the acceptation of new varieties resistant to the other insect pest, herbicide tolerant or others like drought stress resistance when these varieties could be commercialized. However, most of **opportunities** for both systems come from their own weaknesses (Table 8). The use of Trichogrammas for the biological control of ECB is a technology widely used in some European countries (i.e. France) an it may be an opportunity for maize cropping systems in the Ebro Valley if the price is reduced and the technology adapted to the local conditions. In a similar way, the development of mating disruption technology may also reduce the cost application and may be useful for controlling corn borers and other lepidopteran pests. This aspect is very important for MCB who is only effectively controlled by using Bt maize.

Very low proportion of maize surface is really cultivated under IPM guidelines in the Ebro Valley. One of the reasons is the difficulty to know economic thresholds. Therefore, forecast systems need to be developed. This is not an easy task and specific research should be developed with the corresponding investment. Systematic monitoring with adequate techniques, economic threshold determination and prediction models are essential pieces for forecasting. One of the main components of IPM is biological control. Many pest populations may be maintained under economic thresholds if the natural equilibrium with antagonists is not altered. For that, the role of natural enemies should well understand and to enhance the

establishment and development of local natural enemies species. In this sense, rotated maize is more prone to the enhancement of natural enemy populations, especially if alfalfa is included in the crop rotation.

One more **opportunity** is to reduce quantities of nitrogen in fertilizing maize. The amount of nitrogen applied to the crop should be in accordance with the crop requirements and extra amounts do not increase yield but also favourize sap sucking insects for example. Nitrogen reduction may be easier in rotated maize because some crops in the rotation may supply nitrogen to the soil.

Rotated maize is a more buffered system against invasion of new pests. An example is *Diabrotica* as has been well reported in USA and Central Europe but also for some weeds. Although rotated maize is a more complex system than monoculture and farmers need a better knowledge about crop technology and machinery, it is also an educational opportunity. The complexity of maize rotation also favourites farmers association for the use of equipments or other reasons, resulting in the reduction of cost production.

One of the **threats** of the Ebro Valley maize systems is the adoption of restrictions and new requirement for cultivating some kind of varieties, i.e. Bt-maize. This is a widely spread technology in the region (65% of the maize surface) and the only effective method against the MCB. Monoculture is more depending o maize price, for this reason more susceptible to the market fluctuations.

Agricultural policy is crucial for maize crop production in the Ebro Valley. Funds for developing forecast systems and to achieve the needed knowledge for implementing IPM should be available. Moreover, subsidies that encourage farmers to adapt IPM strategies could help very much in order to make new strategies a sustainable option with longer term benefits and demonstrating the economically competitiveness with current strategies.

CONCLUSIONS

Two maize systems were identified in the Ebro Valley. The most widely spread was maize under rotation which includes maize grain production and silage maize. The second system was maize monoculture. Arthropods and weeds were the major problems and there were no significant differences between systems. Corn borers (MCB and ECB) were the main arthropod pest. Current control strategies against pest and weeds are similar between systems. Bt maize resistant varieties to corn borers are widely adapted in the region (65% of the maize cultivated area). Also advanced practices in both systems are quite similar. However, rotated maize systems are more prone to the breakdown of pest cycle, enhancement of natural enemies and nitrogen input reduction, especially if a crop as alfalfa is was included in the crop rotation. Forecast systems needs to be developed for a real cultivation under IPM systems, for that are necessary funds for applied short time research and farmer subsidies to help them to adapt new IPM technologies and make maize production sustainable.

Figure 1.- Ebro Valley region.

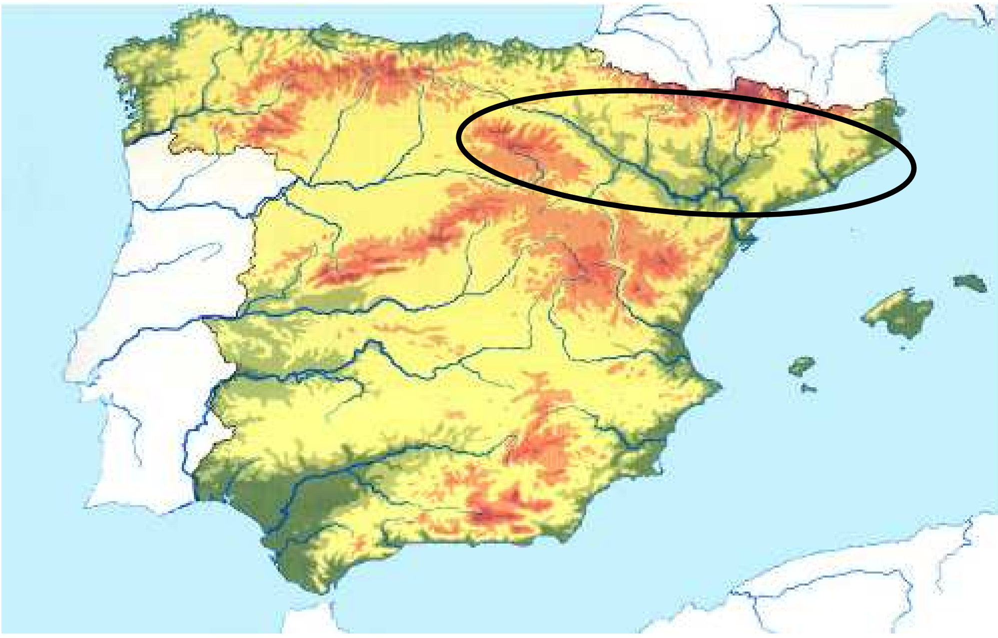


Table 1.- List of experts from the Ebro Valley maize growing region.

Name	Institution and expertise
Ramon Albajes	Universitat de Lleida. Entomologist
Carlos Cantero	Universitat de Lleida. Agronomist
Pere Costafreda	Cupasa Services. Arable crops technical adviser
Matilde Eizaguirre	Universitat de Lleida. Entomologist
Jaume Lloveras	Universitat de Lleida. Agronomist
Juan Pedro Marín	Universitat de Lleida. Plant Pathologist
Carlos Martín	Monsanto España. Technical adviser
Josep Piqué	Cooperativa Sant Gaietà Almenar. Farmer
Xavier Pons	Universitat de Lleida. Entomologist
Andreu Taberner	Generalitat de Catalunya. Universitat de Lleida. Weed Scientist
Lluís Xanxo	Cooperativa Pirenaica. Agronomist and Technical adviser

Table 2.- Current and advanced practices against insect born viruses in the different maize based systems of Ebro Valley.

Practices	MS5 - MS1	MS7
Removal of crop residues	x	x
Crop resistance	X	X
Early sowing	x	x
Delay sowing	X	X
Seed treatments	x	x

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance

Table 3.- Current and advanced practices against corn borers in the different maize based systems of Ebro Valley.

Practices	MS5 - MS1	MS7
Removal of crop residues	X	X
Field margin management	X	x
Early detection	X	X
Major tillage	X [(1)]	X
Minor tillage	X [(1)]	X
Crop resistance	X	X
Crop choice in rotation	X	
Variety choice	X	x
Early sowing	X	
Delay sowing		x
Mating disruption	X (MCB)	X (MCB)
Pesticides	X	X
Conservation and increase of natural enemies	X	x
Inundative Biological Control with Trichogramma	X(ECB)	X(ECB)

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance
[(1)] = No in non-tillage systems (mainly MS1)
MCB = Mediterranean corn borer
ECB = European corn borer

Table 4.- Current and advanced practices against wireworms and cutworms in the different maize based systems of Ebro Valley.

Practices	MS5 – MS1	MS7
Early detection	X	X
Major tillage (ploughing)	X	X
Minor tillage (harrowing)	x (Cw)	x (Cw)
Crop resistance	X (Cw)	X (Cw)
Crop choice in rotation	N	
Pesticides	X (Cw – MS1)	
Seed treatments	X	X
Conservation and increase of natural enemies	X	x

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance
Cw = cutworms

Table 5.- Current and advanced practices against sap sucking insects and spider mites in the different maize based systems of Ebro Valley.

Practices	MS5 – MS1	MS7
Field margin management	X	x
Early detection	X (SS)	X (SS)
Crop choice in rotation	X	
Plant nutrition	X (SS)	X (SS)
Irrigation management	X (M)	
Seed treatments	X (SS)	X (SS)
Pesticides		x
Conservation and increase of natural enemies	X	x

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance
SS = sap sucking insects
M = mites

Table 6.- Current and advanced practices against heliothis and lepidopteran leaf feeders in the different maize based systems of Ebro Valley.

Practices	MS5 – MS1	MS7
Crop resistanece	X	X
Crop choice in rotation	X	
Field margin management	X	x
Pesticides	X	X
Mating disruption	X	x
Conservation and increase of natural enemies	X	x

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance

Table 7.- Current and advanced practices against weeds in the different maize based systems of Ebro Valley.

Practices	MS5 – MS1	MS7
False seedbed	X	X
Crop choice in rotation	X	
Field margin management		x
Delay sowing	X	X
Plant nutrition	x	x
Dealy fisrt irrigation	x	x
Band treatment of herbicides	X	X
Pesticides	X	X

x, X = current practice of minor or major importance
x, X = advanced practice of minor or major importance

Table 8. SWOT analysis of MCBS in the Ebro Valley.

MS5 – MS1	MS7
Strengths	
High yield under current crop conditions	High yield under current crop conditions
Breakdown of pest cycles and potentially less pest pressure	Simpler crop system
Better weed control	Better irrigation tecnology
Irrigation technology	Bt-maize technology adapted
Bt-maize technology adapted	Lower incidence of corn borers and mycotoxins by Bt maize adoption
Lower incidence of corn borers and mycotoxins by Bt maize adoption	
Availability for enhancing natural enemies	
Diversification: system not depending on maize only	
N reduction	
Improvement of soil structure	
Weaknesses	
More complex system: farmers needs more technology and equipment	Potentially most pest pressure
N fertlization	N fertilization
Not ready for BC of ECB (price and technology)	Not ready for BC of ECB (price and technology)
Preventive pesticides applied	Preventive pesticides applied
No forecast systems	Preventive pesticides applied
No effective control of MCB without Bt maize	No effective control of MCB without Bt maize
Rotaion crops as virus reservoirs	More risk of MCB 1st generation
	More risk if WCR invades
	More difficult enhancement of natural enemies
Opportunities	
Acceptation of other GMO varieties	Acceptation of other GMO varieties
CB with Trichogrammas for ECB	CB with Trichogrammas for ECB
Forecast systems	Forecast systems
IPM development	IPM development
N fertilization fitness	N fetilization fitness
Maintain alfalfa for N reduction and natural enemies enhancement	
Improvement of irrigation systems	
Buffering WCR potential expansion if invasion	
Association for equipments use	
Threats	
Environmental concerns: restrictions and new requirements	More dendent on maize price
Support policy	Environmental concerns: restrictions and new requirements
	More depending on support policy

3.4. SWOT Analysis in the selected region in France

Description of 3 production basins in south-western France

Expert Based Survey
ARVALIS – Institut du végétal

Introduction

In France maize is grown on approximately 3,100,000 ha, equally divided between grain and forage maize (Annex 1: Maize in France). There are around 580,000 ha of maize in southwestern France, 75% of which produce grain maize and 17% produce forage maize. It is worth noting that around 8% of that area is used to produce sweet corn and seed maize.
ARVALIS carried out a descriptive study of the different maize production basins, each with homogeneous types of land, based on the following criteria: crop types, maize cropping techniques, soil types, climatic resources, agricultural infrastructure (irrigation…), yield levels of maize as well as other crops, typology of bio-aggressors... This helped identify six main maize production basins in southwestern France (Annex 2 : Maize area in South-West of France). Out of those, 3 production basins were chosen for their specificity, as the basis for a detailed descriptive study:

- "Touyas" land (black soil), circa 57,000 ha
- "Sandy" area (forest land), circa 63,000 ha
- The Garonne valley, circa 97,000 ha

Description of the cropping systems implemented on "Touyas" land:

Maize is grown continuously, as a monoculture, over an estimated 57,000 ha. It is mainly destined for the grain maize market [MS8] (80% of the area – See annex 2). Around 20% of the area is used to grow forage maize [MS4] (used as feed for dairy cows). Deep soil, rich in organic matter, produces consistently high yields (above 10 T of grain maize per ha on average). Only a very small proportion is irrigated.

General typology:

The deep silty soil has a high organic matter content (ranging between 4% and 6%). The vast majority of fields are drained.
Farms are small (between 30 and 70 ha). The median field area is 3.8 ha (80% of fields are between 2 ha and 9 ha). The ratio between the maize area and the total geographical area is extremely high. However, grass margins with permanent green cover also feature strongly.

Climatic resources:

Weather resources provide 2,000 day-degrees (6℃ basis) between 20th April and 15th October, which makes it possible to grow varieties with late and even very late indices. Pluviometry is high: cumulative rainfall is above 200 mm in June, July and August one year in two.

Description of the cropping system:

Soil with good field capacity and good climatic resources (temperature, rainfall) produce conditions particularly well suited to maize growing. Yields average around 10 T/ha with relatively little variation from one year to the next (around 2 T/ha). The best fields often yield up to 12.5 T/ha. In those conditions, other crops cannot possibly compete, neither from a technical point of view (very high risk of disease), nor in economic terms. There is a significant yield and margin difference between maize and other crops.

Description of maize cropping techniques:

The majority of fields are ploughed (>90%). Sowing takes place between 20th April and 10th May. Crop density is relatively low (between 70,000 and 73,000 plants per hectare).
Among the varieties best suited to the climatic resources of that area, farmers prefer high yielding ones, especially those with consistent yields based on the results obtained in

previous years. Farmers are also looking for varieties with good resistance to lodging prior to harvest as harvesting can sometimes be late and take place several weeks after full physiological maturity has been reached.

The weed flora comprises dicotyledons (*Chenopodium album, Solanum nigrum, Amaranthus, Polygonum persicaria*) and summer grasses (*Echinochloa crus-galli, Digitaria sanguinalis, Setaria sp.*). Grasses can reach very significant density levels and re-emergence presents a real problem until mid-June. New dicotyledonous weeds have been appearing since the withdrawal of atrazine in 2003 (*Datura stramonium, Abutilon theophrasti, Xanthium*). This geographical area is characterised by frequent rainfall in May and June. In addition, the ground must be allowed to drain off and dry for quite a long time before tillage. This solclime is hardly compatible with post-emergence weed control, especially for grasses, and the application date must be adjusted depending on the growth stage of the weeds. For all those reasons, farmers carry out post-sowing and pre-emergence weed control in 70% of cases. The graminicide active ingredients used are acetochlor, *S-metolachlor*, DMTA-P, mixed with an *isoxaflutole* based dicotyledonicide. Soils having high organic matter contents, the herbicide rates applied by farmers are close to approved full rates. In 25% of cases, weed control measures are carried out as the crop is being sown (with special drill mounted equipment). In 25% of fields, weed control is carried out using a pre-emergence graminicide after sowing (*acetochlor, S-metolachlor, DMTA-P*), followed by a post-emergence application (*mesotrione, sulcotrione, bromoxynil, bentazone*). Post-emergence rates applied are often 30 to 50% of the approved rate. In only 5% of cases, farmers use no pre-emergence herbicide and choose to concentrate entirely on post-emergence weed control (with the addition of a sulfonylurea such as *nicosulfuron*). Again, application rates are reduced (to between 30% and 50% of the approved rate in one or two applications). This strategy carrying some risks, its efficacy varies from year to year, and, on average, it is expensive. In this area, successful weed control requires pre-emergence action, especially to limit the harmful effect of grasses. *Convulvus arvensis* needs to be controlled in 30% of the maize area (with significant variations from one year to the next).

A few farmers control weeds mechanically but both weather conditions and high weed density make this a risky technique. Conversely, all maize crops are fertilised at the 10-12 leaf stage. The inter-row gap is hoed at the same time (with a tine on either side of the fertiliser coulter), which helps eliminate re-emerging weeds when there are not too many and they are still fairly small (Annex 3: Weeds management).

The main two diseases are *Trichometasphareria turcica* (or *Helminthosporium turcicum*) on the leaves and *Fusarium sp.* on the ears. To control both those diseases, farmers implement prophylactic measures in order to reduce risks (Annex 4 : Desease) : they chop the residue of the previous maize crop and incorporate it into the ground to begin its degradation, they choose varieties that are not very susceptible to those pathogens (varietal grading published by ARVALIS annually), and they sow early in order to limit disease development and its impact on yield. If farmers did not use varietal resistance to control *Trichometasphareria turcica*, it is estimated that this disease would be harmful to crops on average every three years.

The problems caused by insects are mainly due to ground pests. Wireworms are the main problem: their presence is felt throughout the whole geographical area and causes very severe damage. They can lead to yield penalties of up to 80% in some fields where attacks are particularly severe and no control measures are implemented. All maize crops in this area must be protected with insecticide against wireworms. Farmers use seed treatment with insecticide as they sow (thiamethoxam in 2008 and 2009) or as they apply microgranules into the sowing row (pyrethroid family). This chemical protection must be combined with agronomical measures (Annex 5 : Protection against arthropods) : varieties with fast early development, and fertilisation at sowing time in order to shorten the period when maize

plants are susceptible to wireworm attacks. No other agronomical or biological control method is effective enough to protect maize against wireworms. It is impossible to grow organic maize in this production basin, as no solution compatible with this mode of farming is effective enough to protect crops from wireworm attacks.

The other ground pest present in this area is *Scutigerella immaculata*. This myriapod attacks a smaller area than wireworms. But current control solutions are only partially effective. The damage they cause is found more commonly in min-till systems. The control methods recommended to reduce the harmfulness of *Scutigerella immaculata* include ploughing, choosing a variety with fast early development and fertilising at sowing time. The protection provided by pyrethroid based microgranules applied into the sowing row, helps to reduce the damage caused by *Scutigerella immaculata* attacks. This pest causes most significant damage where a min-till system is implemented.
Some years, a few cutworms (*Agrotis sp.*) may justify an insecticide application at the early stage (less than 10% of the area is affected).

What place is there for other crops in the rotation?
Maize is grown continuously, as a monoculture. Other crops encounter significant problems in relation to diseases (e.g.: septoria in cereals). The difference in yields and margin between grain maize and possible replacement crops is very significant. In addition, the introduction of one or several other crop(s) into the rotation would not help to resolve the main technical problem in maize, which is wireworms. The only possible advantages would relate to weed control, which is currently satisfactory through the use of pre-emergence graminicides, and leaf diseases, which are currently controlled through varietal resistance.

Agronomical and solclime conditions are suited to maize growing. A large proportion of this production is utilised as feed for the livestock in the area (grain maize for pigs and forage maize for dairy cows). Significant maize areas in this geographical zone are also grown for specialist sectors (waxy maize, seed maize, sweet corn). Maize monoculture plays an important role in the economy of local sectors.

Description of the cropping system in forest soils of the Aquitaine region (sandy soils):
Permeable soils cover around 63,000 ha and are divided into two main types: clayey-chalky soils, in the northern part of the region (southwestern France), and forest soils of Aquitaine where maize covers around 50,000 ha (Annex 2: Maize area in South-West of France). This production basin is characterised by high grain maize yields due in part to the fact that irrigation water resources are sufficient and not a limiting factor. 90% of the grain maize area is used for monoculture and is irrigated [MS7]. Sandy soil conditions and farming infrastructure (sufficient irrigation water resources) help to grow contractual crops with high added value (carrots, green beans, sweet corn...). 10% of the area that cultivate other crops [MS5]. Forage maize areas are insignificant.

General typology:
The soil contains 95% sand. The organic matter content is extremely variable: from less than 1% to over 4% depending on the history of the area (former marsh). Generally, soils are shallow (between 30 cm and 1 m). Therefore soil capacity of water is low (20 to 50 mm).
Farms are large (between 50 ha for the smallest and nearly 1000 ha for the largest). The median field area is 26.5 ha (80% of fields are between 10 ha and 150 ha). The effective agricultural area is small in comparison with the size of the geographical area. Pine forest covers over 85% of the geographical area.
Climatic resources:
Weather resources provide between 1930 and 2130 day-degrees (6^{o}C basis), depending on the location, between 20th April and 15th October, which makes it possible to grow varieties

with semi-late to very late indices. Total pluviometry for June – July – August ranges from 150 mm to 180 mm one year in two.

Description of the cropping system:
This production basin is characterised by low field capacity and low pluviometry. Irrigation is not a limiting factor (100% of maize evapotranspiration covered), and yield levels are consistently high: they can reach an average of 13 T/ha, with yields of up to 15 T/ha on the best farms in some years. Only contractual crops, especially vegetables (mainly carrots, green beans and sweet corn), can compete economically with such high maize yield levels. The area devoted to them varies from year to year, but is always fairly limited because of the limited market.

Description of the maize cropping techniques:
The majority of fields are ploughed (>80%). However, the area on which min-till is implemented has been growing over the last few years. Sowing takes place between the beginning of April and 5th May. Crop densities are high (above 85,000 plants per hectare).
Farms being large, farmers sow a range of varieties with different earliness. This helps to spread out harvest over several weeks, between 20th September and 1st November. It means that their harvest work matches the throughput of their own dryer (high level of drying and storage equipment on farms). Among the list of varieties best suited to the climatic resources of that area, farmers prefer high yielding ones, and then those with consistent yields in years. In addition, farmers look for varieties with good levels of resistance to lodging during growth. The risk of lodging during growth is high due to the proximity of the ocean (wind), as well as due to the light soil. Resistance to leaf blight and ear fusarium are essential criteria that must be heeded when choosing which variety to grow (see below).

The weed flora is made up of dicotyledons (*Chenopodium album, Solanum nigrum, Amaranthus, Polygonum persicaria,* and locally *Portulaca oleracea*) and summer grasses (*Digitaria sanguinalis, Echinochloa crus-galli, Setaria sp.*). New dicotyledonous weeds have been appearing since the withdrawal of atrazine in 2003 (mainly *Datura stramonium*,). The soil being permeable, fields drain and dry very quickly and load bearing capacity is not a problem. This explains why only post-sowing pre-emergence weed control (acetochlor, s-metolachlor, isoxaflutole, mesotrione) is carried out on less than 35% of the maize area of this zone. On around 35% of the maize area, post-sowing pre-emergence weed control (acetochlor, s-metolachlor) is followed by a post-emergence application (mesotrione, sulcotrione, bentazon, bromoxynil). On the remaining 30% of the maize area, weed control takes the form of 1 or 2 post-emergence applications (sulcotrione, mesotrione, nicosulfuron). When the organic matter content of the soil is lower, post-sowing pre-emergence rates are reduced (applied rate amounts to 75-80% of the approved rate). Soil load bearing conditions presenting few problems, treatments can be applied at optimum weeds stages, and product rates can therefore be adjusted: post-emergence rates often range between 20 and 50% of the approved rate.

Convulvus arvensis needs to be controlled in 15% to 20% of the maize area (with significant variations from one year to the next).
Soil characteristics (described above) make mechanical weed control possible. At the beginning of the decade, a large proportion of farmers combined post-sowing pre-emergence chemical weed control with a post-emergence mechanical one. However, mechanical weed control is slower than chemical applications. This is why many farmers with large areas prefer chemical post-emergence weed control. For mechanical weed control to continue to develop, further technical progress will have to be achieved in order to improve work rate and reduce its energy cost (Annex 3 : Weed management).

The main two diseases are *Trichometasphareria turcica* (or *Helminthosporium turcicum*) on the leaves and *Fusarium sp*. on the ears. To control both those diseases, farmers implement

prophylactic measures in order to reduce risks (Annex 4 : Desease) : they chop the residue of the previous maize crop and incorporate it into the ground to encourage its degradation, they choose varieties that are not very susceptible to those pathogens (varietal grading published by ARVALIS annually), and they sow early in order to limit disease development and its impact on yield. An early attack of *Trichometasphareria turcica* on a susceptible variety can result in 20% to 40% yield losses.

Three main pests could cause serious damage (Annex 5) : *Pratylenchus sp*, *Laodelphax striatellus* that are likely to spread the Maize Rough Dwarf Virus, and Mediterranean Corn Borers (*Sesamia nonagrioides*).

There are currently no approved nematicides to control nematodes in maize crops. The only solution available to maize growers is to choose a variety with fast early development, and to use a basal fertiliser at sowing time (18-46, in order to apply nitrogen and phosphoric acid). Yield losses vary from year to year: when spring is cold (limiting maize growth) and wet (encouraging attacks by nematodes), yield losses can reach up to 15% - 20%. Plants established during the intercropping season to break the *Pratylenchus sp*. cycle would help to limit the harmfulness of those nematodes. No such species suitable as cover crops have been identified yet.
In order to control MRDV, farmers must choose varieties that are not very susceptible to this virus (varietal screening is currently at an experimental stage).

Mediterranean Corn Borers cause damage of an extremely variable magnitude from year to year, with significant attacks resulting in losses of up to 10%. Most losses result from stems breaking before harvest (due to them being made fragile) and reduced safety quality, including a significant increase in fumonisine levels. Prophylactic measures consist of chopping the residue of the previous maize crop before the larvae take refuge inside the bottom of the plant. Weather conditions have a significant bearing on the survival rate of the Mediterranean Corn Borer. Finally, ploughing helps to eliminate part of the larvae that survived the winter. During plant growth, ovicide (diflubenzuron) or larvicide (synthetic pyrethroids) chemicals are used to control the first generation of insects. Treatment rates vary by 10% to 50% from year to year, depending on the level of Mediterranean Corn Borer attacks observed the previous year. Two of the possible research routes to develop new control techniques are sexual confusion and finding natural enemies of the Mediterranean Corn Borer (Annex 5 : Protection against arthropods).

What place is there for other crops in the rotation?
High grain maize production levels make other crops of little interest. Contractual crops are the only ones that can possibly compete economically with grain maize. The technical advantage provided by the introduction of other crops into the rotation resides in weed control management (not the main problem). Nematode control is technically possible in carrot crops (nematicid). Being cost-effective, this crop is often grown in this area.

Subsequent maize crops grown in fields that were disinfected to produce carrots benefit from this protection. Conversely, Mediterranean Corn Borers being an airborne pest, crop rotation does not help reduce the risk.

This production basin provides conditions (irrigation and water resources) which are favourable to grain maize production and result in high yields, regardless of weather conditions. This solclime has made it possible for farmers to specialise in maize production (drying and storage equipment is commonly found on farms). However, those farming conditions are also favourable for producing contractual crops such as vegetables (carrots, green beans) or specialised maize crops (sweet corn, seed maize, waxy maize).

Description of the cropping system in the Garonne Valley:
This production basin comprises around 97,000 ha of irrigated grain maize, 95% of which is grown continuously, as a monoculture [MS7]. Similar cropping techniques are used throughout this grain maize production area, which is a representative example of maize cropping in valley conditions.

General typology:
The alluvial soil is typical of a valley, with a high proportion of silt (over 50%), then clay and sand. The size of silt particles, and the proportion of clay and organic matter have a strong bearing on soil behaviour, especially regarding capping, and therefore on the type of soil cultivation carried out by farmers prior to sowing. Stony soils, however, are fairly rare.
Farms are of medium size, ranging from 30 to 80 ha, and practise polyculture (multiple crop farming), with maize, cereals, sunflowers, and sometimes vegetables or perennial crops. 80% of fields are between 2 ha and 9 ha. The median field area is under 3 ha in this production basin.

Climatic resources:
There are significant climatic variations, with a cold zone upstream (southern part upstream of Toulouse): the accumulated temperature (on a 6℃ basis) is 1920 day-degrees between 20th April and 15th October 4 years in 5. Further north (between Toulouse and Agen), the accumulated temperature reaches 2100 day-degrees. The pluviometry is higher in the south (nearer the Pyrenees range) and significantly lower in the north. Accumulated pluviometry for June - July ranges from 160 to 200 mm 5 years in 10.

Description of the cropping system:
Field capacity is relatively limited. Maize fields are irrigated (rotating boom or hose reels). Water resources, added to the pluviometry, manage to cover between 80 and 100% of maximum evapotranspiration in maize crops, depending on the situation. Yields vary depending on the geographical area, the field, and weather conditions during the cropping season. They are estimated at around 11.5 T/ha on average. Yields of up to 14.5 T/ha can however be achieved in some situations. Variations between years stand at over 2.5 T/ha. Maize, and particularly grain maize, is the crop providing farmers with the highest income, by utilising summer climatic resources. However, those technical results are only possible with irrigation.

Description of the maize cropping techniques:
Sowing takes place between 1st and 25th April, depending on the year. Crop densities are high with 80,000 to 85,000 plants per hectare.
Farmers prefer varieties with very high yield potential, within an earliness window suited to local climatic resources. Other varietal criteria include fast early development, excellent resistance to lodging during growth (some areas are exposed to high winds) and tolerance to ear diseases. There are no risk of development of leaf diseases in this production area. In years to come, varieties with rapid grain desiccation will continue to be favoured in order to reduce drying costs.

The weed flora comprises summer grasses (*Echinochloa crus-galli, Digitaria sanguinalis, Setaria sp.*) and common dicotyledons (*Chenopodium album, Solanum nigrum, Amaranthus, Polygonum persicaria*). New dicotyledonous weeds have been appearing since the withdrawal of atrazine in 2003 (*Datura stramonium, Abutilon theophrasti, Xanthium*). The soil, very high in silt and poor in organic matter, is highly prone to compaction, which almost precludes the possibility of spraying on the days following a rain event. In addition, the number of days with winds over 18.5 km/h (3 on the Beaufort scale) is high in May and at the beginning of June. Finally, temperatures can be high (despite a sometimes high level of pluviometry), and grasses very quickly grow beyond the stage when they are sensitive to the herbicides approved for post-emergence use. All those factors risk compromising the

effectiveness of post-emergence weed control. Farmers implement a complete post-sowing pre-emergence weed control programme in 75% of cases, using acetochlor, S-metolachlor, DMTA-P, isoxaflutole and mesotrione. In 20% of cases, weed control is carried out post-sowing and pre-emergence, using acetochlor, S-metolachlor, DMTA-P, followed by another post-sowing treatment with sulcotrione, mesotrione, nicosulfuron. Post-emergence weed control (in one or two applications), with no pre-emergence treatment, is carried out on less than 5% of the area (nicosulfuron, mesotrione, sulcotrione). *Convulvus arvensis* needs to be controlled using dicamba on 15% to 20% of the maize area (with significant variations from one year to the next). Deciding on the timing of applications is sometimes difficult as there can be a large difference in temperatures from one day to the next.
The soil, very silty, poor in organic matter and sometimes stony, is not suitable for mechanical weed control. The solclime allows very little leeway concerning weed control, and weed control strategies look unlikely to change in this production basin in the future.

There are very few cases of leaf disease in the Garonne Valley. Conversely, ear *Fusariums sp.* can be a problem in some years, depending on weather conditions during the second half of the maize cycle and levels of borer infestation. In order to limit risks, farmers must favour *Fusarium graminearum* and *Fusarium verticilloïdes* tolerant varieties (varietal grading published by ARVALIS annually). Early sowing also improves the chance of yields reaching their full potential as well as of limiting the impact of ear diseases. Finally, borer control can also be implemented (see below).

The two types of maize pests causing the most damage are *Zyginidia scutellaris* and borers *Ostrinia nubilalis* and *Sesamia nonagrioides*. Some years *Agrotis segetum* and *A. ipsilon* can also cause damage. Conversely, there is a relatively limited risk of ground pest (*Agriotes sp.*, *Scutigerella immaculata*) attacks.
In the 1990s, a large proportion of the maize area in the Garonne Valley was protected with imidacloprid as seed treatment in order to reduce the harmfulness of leaf hoppers. Since the withdrawal of the product containing this active ingredient in 2005, farmers have no means of protecting their crops against this pest. The level of harmfulness ranges from 5% to 30% depending on the year and hydric conditions. Farmers can only implement evasive measures, such as sowing earlier and using a basal fertiliser at sowing time. However, this type of protection is only partially effective.

Ostrinia nubilalis and *Sesamia nonagrioides* are the most commonly found airborne pests in this production basin, and their level of harmfulness can reach up to 2 T/ha in some years. Each of those species has two cycles per year. The first moth flight takes place between mid-May and mid-June. A second flight occurs between mid-July and the end of August. A third flight may happen in exceptionally hot years. The damage, in economic (yield loss) and safety quality (entry route for *Fusariums sp.* which encourages mycotoxin production like DON, Fumonisins), is caused by the second generation. Farmers not being equipped to control this generation (requires a high clearance tractor), most borer control measures are implemented against the first generation, using synthetic pyrethroid based insecticides (treatment before final possible tractor pass). Limiting the size of the first generation population aims to reduce the harmfulness of the second. Trichogramma wasps are not very useful in this production basin, due to the concomitant presence of *Sesamia nonagrioides* (a species against which trichograms have no effect). Trichogramma wasps will become useful as a biological control method, if an alternative to pyrethroids is developed in order to specifically control Mediterranean Corn Borers (natural enemies, mating disruption). It is currently impossible to use borer resistant GM varieties in France. But in 2007, when it was possible to grow GM crops in France, there were nearly 15,000 ha of European and Mediterranean corn borer resistant GM maize in the Garonne Valley.

What place is there for other crops in the rotation?

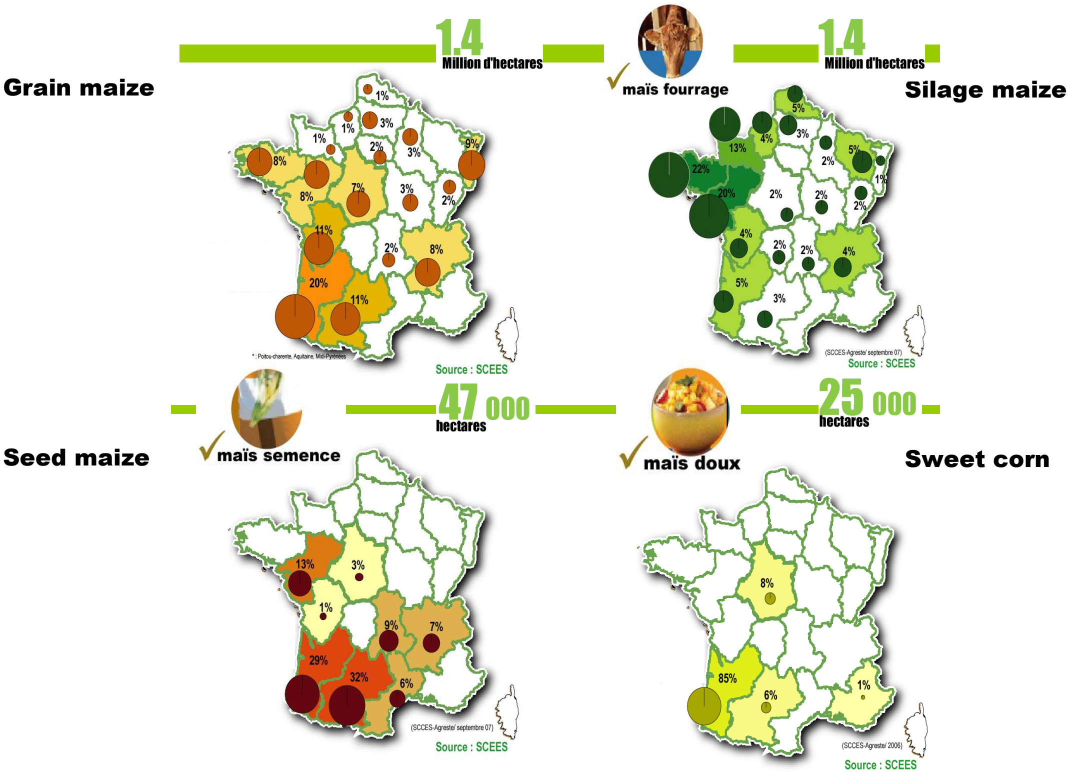
Some crops may be introduced into the rotation, such as soft wheat, wheat (ear fusarium problems following maize) and sunflowers. The major disadvantage of such a practice would be not to utilise the irrigation equipment and water resources. It would reduce the cost-effectiveness of the system. Technical advantages would be limited to weed control. The main pests are airborne (and therefore not inherent to the field) and diseases are not a major problem in this production basin.

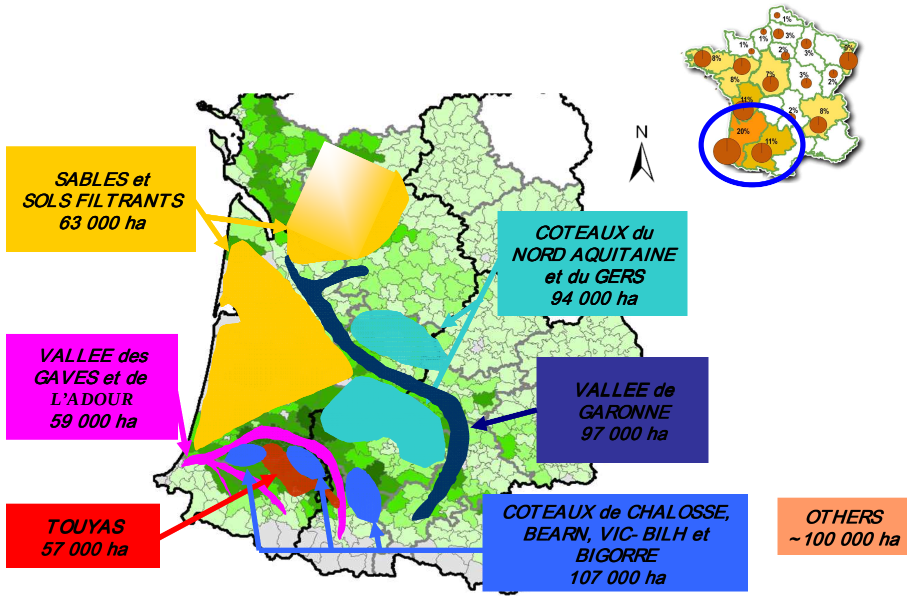
Like in many other European valleys, grain maize is a crop which is economically and technically suited to the sol clime of the Garonne Valley. Irrigation helps achieve high yields. Weed control is the most important issue in the choice of cropping techniques in order to make maize production possible in this area. The problem of mycotoxin (DON, Fumonisins) is important and farmers have to fight corn borers in order to maintain quality and yield of maize.

Conclusions on current practices:

- Early sowing and management of crop residues to reduce deseases
- Variety choice against *Fusarium* and *Trichometasphaeria turcica*
- Major tillage against *Trichometasphaeria turcica, Scutigerella immaculata,* MCB
- Seed treatments and pesticides against wireworms, *Scutigerella immaculata*, MCB, ECB and weeds in all systems concerned
- Conclusions on innovative practices :
- Early sowing against *Fusarium* and *Trichometasphaeria turcica*
- Crop resistance against *Fusarium*, mains arthropods and weeds
- Weeds control with hoeing machine. Crop choice in rotation is not a solution because others crops are not profitable.

Annex 1 : Maize in France





Annex 2 : Maize area in South-West of France

Annex 3 : Weeds management

Measures	Deep soil, organic matter MS4 / MS8	Sand soil MS5 / MS7	Alluvial soil of valley MS7
False seedbed			
Hoeing machine	x	X	x
Early detection			
Major tillage (ploughing)			
Minor tillage (harrowing etc.)			
Early sowing	x	x	x
Crop resistance	X	X	X
Interow cultivation			
Cleaning of harvester			
Crop choice in rotation	x *(No profitable)*	x *(No profitable)*	x *(No profitable)*
Pesticides	X	X	X

x, X = current practice of minor or major importance
x, X = innovative practice of minor or major importance

Annex 4 : Diseases

Trichometasphaeria turcica

Helminthosporium turcicum (Pass.)

Measures	Deep soil, organic matter MS4 / MS8	Sand soil MS5 / MS7
Grinding of crop residues	X	X
Early detection		
Major tillage (ploughing)	X	X
Crop resistance		
Crop choice in rotation	X *(No profitable)*	X *(No profitable)*
Variety choice	X	X
Early sowing	x	x
Plant nutrition		
Pesticides	X (not used)	X (not used)
Seed treatments		

x, X = current practice of minor or major importance
x, X = innovative practice of minor or major importance

Annex 4 : Diseases Fusarium (ear)

Measures	Deep soil, organic matter MS4 / MS8	Sand soil MS5 / MS7	Alluvial soil of valley MS7
Grinding of crop residues	X	X	X
Early detection			
Major tillage (ploughing)	x	x	x
Crop resistance	X	X	X
Crop choice in rotation	X (No profitable)	X (No profitable)	X (No profitable)
Variety choice	X	X	X
Early sowing	X / X	X / X	X / X
Plant nutrition	X	X	X
Pesticides			
Seed treatments	x	x	x
Pest management (ECB, MCB)	x / x	X / X	X / X

x, X = current practice of minor or major importance
x, X = innovative practice of minor or major importance

Annex 5: Protection against arthropods

Measures	Wireworms Deep soil, organic matter MS4 / MS8	Scutigerella immaculata Deep soil, organic matter MS4 / MS8
Removal of crop residues		
Early detection	X[1]	
Major tillage (ploughing)		X
Crop resistance	X	X
Crop choice in rotation		
Variety choice	x	X
Early sowing		
Plant nutrition	x	X
Pesticides	X	X
Seed treatments	X	
Natural ennemies[2]	X[2]	X[2]

[1] : Prediction of risk in the field and climatic conditiond of the year

[2] : Parasitoïdes, pathogens

x, X = current practice of minor or major importance
x, X = innovative practice of minor or major importance

Annex 6: Protection against nematodes

Measures	Nematods Sand soil MS5 / MS7
Removal of crop residues	
Early detection	
Major tillage (ploughing)	
Crop resistance	
Crop choice in rotation	X[1]
Variety choice	X
Early sowing	
Plant nutrition	X
Pesticides	
Seed treatments	

[1] : Plants cut cycle of nematods

x, X = current practice of minor or major importance
x, X = innovative practice of minor or major importance

3.5. SWOT Analysis of MBCS in North regions

Northern region: The Netherlands, Denmark and Northern Poland
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INTRODUCTION
BACKGROUND OF MAIZE CULTIVATION IN THE NORTHERN REGION
Maize is cultivated 240.000 ha in the Netherlands of which 98% is grown for silage maize and 2% for grain maize. The cultivated area of maize in Denmark has being steadily increasing within the last 10 years and is now 150.000 ha of which 98% is used for silage and 2% for grain. Cultivation of grain maize is very recent and only practiced in the Southern part of the country. The total maize area in Poland is 320.000 ha of which 185.000 ha is the Northern part of the country. In this part of Poland silage maize constitutes 73% of the cultivated area while 27% is used for grain maize.

In the Netherlands there were subsidies for integrated weed management in maize from 2000 till 2005. IPM is still promoted (www.gewasbeschermingsmaatregelen.nl) but nowadays there are no subsidies anymore. There are no IPM programmes or similar in place in Denmark or Poland. Maize is also grown by organic farmers but the area makes up a very minor part of the total area.

COLLECTION OF INFORMATION ON MAIZE CULTIVATION
The authors of this paper contacted a number of national experts to collect the required information on maize cultivation. Furthermore, information was extracted from the ENDURE Maize Case Study (RA1.2). The following additional experts were contacted:

> The Netherlands: Huub Schepers, Rinske Meier, Hilfried Huiting, Albert Ester and Jos Groten (all Wageningen UR, Applied Plant Production)
> Denmark: Rolf Clausen and Ghita C. Nielsen (Danish Agricultural Advisory Service)
> Poland: Roman Warzecha (IHAR) and Jozef Adamczyk (Smolice Breeding Company)

RESULTS OF THE SURVEY AND SWOT ANALYSIS
CHARACTERISTICS OF MAIZE PRODUCTION IN THE NORTHERN REGION
Two systems were indentified in the three countries. Maize grown continuously (MS4) and maize rotated (MS2). In Denmark some farmers have the possibility to irrigate the crop but basically it is non-irrigated systems in all three countries. If irrigation is used then the crop is typically irrigated once before anthesis. In the Netherlands and Denmark ca. 50% of the maize is grown in monoculture and 50% in rotation. Rotational crop in the Netherlands are grass or arable crops such as cereals, potatoes and sugar beet and in Denmark cereals with undersown grass and grass. A typical rotation in Denmark is cereals with undersown grass, grass, grass and maize, i.e. maize every 4. year.

PESTS IN MAIZE IN THE NORTHERN REGION
The major diseases in the Netherlands are *Fusarium ssp* causing stalk and ear rot, *Helminthosporium ssp* and *Kabatiella zeae* causing leaf spot diseases, *Ustilage maydis*, *Rhizoctonia ssp* and *Phoma ssp*. Important arthropod pests are *Oscinella frit* (frit flies) and wireworms (*Agriotes ssp*). Among the weeds the annual grasses *Poa annua*, *Echinochloa crus-galli* and *Setaria viridis*, the annual broad-leaved weed species *Stellaria media*,

Chenopodium album, *Geranium ssp*, *Polygonum ssp* and *Solanum nigrum* and the perennial weeds *Elymus repens* and *Calystegia sepium* are the most troublesome.

The situation in Denmark is very similar to the one in the Netherlands except that *Helminthosporium ssp* and *Kabatiella zeae* are less common than in the Netherlands but are observed in some years in maize in monoculture. Besides the arthropod pests mentioned above aphids can also be a problem. Concerning weeds *Tripleurospermum inodorum*, *Veronica ssp* and *Viola ssp* are also considered problematic and the perennial weed *Circium arvensis* is more problematic in Denmark than *Calystegia sepium* that is only found locally.

Poland does not differ significantly from the Netherland and Denmark except that *Giberella zeae* causing stalk and ear rot and the arthropod pest *Agrostis ssp* are also causing problems in Northern Poland. Weed flora is very similar except that *Amaranthus retroflexus* is an important weed species in this region.

CURRENT AND ADVANCED PRACTICES IN THE NORTHERN REGION
In the following the current and advanced practices are listed for the key pests.
Fusarium ssp:

Current practices: Inversion tillage, rotation (only MS2), cultivar resistance, early sowing (Poland), avoid sowing in cold soils (the Netherlands and Denmark), seed treatment
Advanced practices: Early detection

Helminthosporium ssp and *Kabatiella zeae*:

Current practices: Inversion tillage, rotation (only MS2), cultivar resistance, plant nutrition.
Advanced practices: None

Ustilaga maydis:

Current practices: Seed treatment
Advanced practices: Cultivar resistance, rotation (only MS2)

Rhizoctonia ssp:

Current practices: Cultivar resistance
Advanced practices: Rotation (only MS2)

Phoma ssp:

Current practices: Seed treatment
Advanced practices: Rotation (only MS2)

Oscinella frit:

Current practices: Early sowing, foliar pesticide application and seed treatment
Advanced practices: None

Aphids:

Current practices: Foliar pesticide application
Advanced practices: Early detection

Agriostes ssp:

Current practices: Seed treatment
Advanced practices: Early detection and rotation (only MS2)

Weeds:

Current practices: False seedbed, field margin management (perennial weeds), inversion tillage, weed harrowing, rotation (only MS2), plant nutrition and residual/foliar pesticide application.

Advanced practices: Early detection, mechanical weed control, low pesticide dose and/or patch spraying, rotation (only MS2) and competitive varieties

PESTICIDE USE IN MAIZE

In Denmark maize is, according to the most recent statistics from 2008, treated on average with 1.4 full doses of herbicides of which herbicides constituted 1,36. The remaining 0.04 treatment frequency was insecticides.

In the Netherlands the average amount of active ingredient per hectare was 1.6 kg in 1999, 0.75 kg in 2004 (subsidized IPM program until 2005) and 0.9 kg in 2008. Except for seed coating, only herbicides are used

SWOT ANALYSIS OF MAIZE BASED SYSTEMS

The SWOT analysis was done for each of the two maize systems: continuous maize (MS4) and maize in rotation (MS2). The situation differs between the three countries and the SWOT analysis is a compilation of the situation and some of the aspects mentioned may only be true for one or two of the countries.

Continuous maize

The strengths of the continuous maize are that it is well suited to a farming system where the maize is used feeding cattle, the farmers tend to be very knowledgeable about maize cultivation, it is a system well suited for hiring contractors with experience and state-of-the-art equipment and it is a convenient system where farmers own land a long distance from the farm and therefore cannot be used for grazing.

The weaknesses of the system are soil degradation (reduced content of organic matter, compaction), relatively high inputs of herbicides, high fertiliser use, nitrogen and herbicide leaching, sub-optimum pH of the soil, farmers leaving the responsibility for crop protection to the contractors, many commercial extension agents and deterioration of the landscape.

Opportunities are to reduce pesticide use through adaption of IPM strategies, improve the choice of variety, improve cultivation practices e.g. with green winter manure crops, ridge tillage, fertiliser band application, non-chemical weed control methods and better targeted herbicide use, GMO maize, development of forecasting models and decision support systems, seed treatment instead of broadcast application, use as biofuel crop, adjustment of soil pH, improved extension services, establishment of fixed tramlines to avoid soil compaction and possibly financial support to promote a more sustainable cropping system.

The threats to the continuous maize system are the build up of specific weeds, arthropod pests or diseases as a result of limited access to pesticides, development of herbicide resistance, environmental concerns, mycotoxin contamination and fluctuating prices on products and inputs.

Maize in rotation

The strengths of this system are that the yields are higher than in continuous maize, weed control is easier because weed flora is not dominated by a few difficult to control weed species and herbicide resistance is not an issue, soil structure is improved by rotation between deep rooted and shallow rooted crops, lower risk for problems with *Helminthosporium ssp* and *Fusarium* and hence reduced risk of mycotoxin contamination and contractors with lot of experience and state-of-the-art equipment are available.

Weaknesses are fluctuating prices of the crops in the rotation (compared to using the maize for silage on the farm), some rotational crops can increase the problems with *Rhizoctonia ssp,* more equipment is needed, many commercial extension agents and farmers are less experienced in growing some of the crops in the rotation.

The opportunities are basically the same as for continuous maize except for adjusting soil pH which is not an issue in rotated maize. Besides these the rotated maize system provides another opportunity and that is price stabilisation due to crop diversification.

The treats to the system are few but build of specific pests due to reduced availability of pesticides is one and environmental concerns and fluctuating prices on products and inputs are two others.

CONSTRAINTS AND CHALLENGES FOR FUTURE DEVELOPMENT

The major constraints for developing innovative systems in maize are economically. Most of the maize grown in the Northern region is used for silage producing cheap feed is the number one priority of the dairy farmers. This is the main reason why the maize area has been increasing in Denmark. Although the yield may be lower than for fodder beet the costs are also lower. Innovative technologies have to be either cheap or provide significant advantages to the farmer to convince him to take them up. The widely adapted practice particularly in the Netherlands of using contractors covering large areas could promote the adaption of new technologies because as they can afford the investment.

Increasing problems with weeds including herbicide resistant biotypes, mycotoxins and leaf spot diseases caused by *Helminthosporium ssp* and *Kabatiella zeae* may eventually force farmers to give up continuous maize and move to the more sustainable rotational system. The anticipated reduction in the number of available active ingredients in the future will push to this development.

A shift from continuous to rotated maize will typically introduce grass crops into the rotation. From an environmental point of view grass is an ideal crop (green cover year around and a very low use of pesticides). However, it should be noticed that pesticide use in maize is the Northern region is generally low, as herbicides are the only pesticides used routinely. Replacing maize by e.g. spring cereals or winter cereals would, in Denmark, result in an increased pesticide use.

An important driver for innovative solutions could be the use of maize for biofuel. To justify this production from an energy or environmental point of view the inputs into the systems including fertilisers and pesticides should be reduced significantly. Although this may be associated with yield losses farmers could be compensated through subsidies if the political climate is in favour of promoting biofuel production.

4. General conclusions

(Action to be taken are listed as bullet points)
Maize is a key crop in the MBCS either in terms of acreages, frequency or role in the crop rotation. However, depending on region (i.e. on regional climatic, farming and economic conditions), the role of maize is different. In the northern region maize is mostly cultivated as silage maize and rotated with grasses, while in central EU regions silage and grain maize are both cultivated. In eastern and southern regions grain maize production is prevalent and a simplified crop rotation is generally rather frequent.

- The adoption of more diversified crop rotations in MBCS is essential. to develop "new" systems that break the biology of pests. However, differences among regions will have to be considered.

Across the considered regions, economic driving forces are key factors for triggering farmers' decision, including those dealing with crop protection issues. Because of this, a multi-year approach (i.e. involving more crops in rotation) is not frequently considered by farmers or even available for implementation.

- Regional policy to encourage sustainable systems based on crop rotation and advanced pest control strategies should be developed. The new Framework Directive on the sustainable use of pesticides could provide a solid basis for this purpose.

Advanced pest control practices such as efficient choice of hybrids (drought and/or disease tolerant), timing of planting, pesticide choice (incl. bio-pesticide), biological control (*Trichogramma* spp. against ECB) and pest forecast methods and control decision have been indicated as valuable tools for sustainable IPM systems. However, a system approach that considers all above tools is still poorly developed at both research and farm level.

- Complex evaluation methods for various options for MBCSs development scenarios are still missing and should be developed. These methods should combine various considerations (environmental, technical, economic, etc.) and wighted with policy aims
- Research on and implementation of system approaches (i.e. at cropping or even farming level), according to different regions, should be encouraged and adopted at various levels

The introduction of innovative practices (Bt maize resistant to ECB, WCR, or herbicide tolerant, precision spraying, improved Decision Support Systems and forecast systems (pest, diseases and weeds monitoring) in IPM strategies can address the EU strategic commitment for a sustainable use of pesticides and consequently more environmentally sustainable MBCS. However, constraints and challenges for their development and implementation should be tackled.

- Applied multi-disciplinary research and farmer incentives to help the adoption of new IPM strategies in MBCS are essential.
- Regional policies that allow the use of GM crops, against ECB, *Diabrotica* or herbicide tolerant against weeds, in regions with heavy infestations would contribute to pesticide use reduction.
- The establishment of a link between stakeholders (i.e. research, industry, consultants, contractors and farmers) can be the basis for a better understanding and efficient use of innovative IPM strategies through mutual information recognition and sharing.