ENDURE

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Tutorial of DEXiPM arable crops

A qualitative multi-criteria model for the assessment of the sustainability of pest management systems

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PU Public	
PP Restricted to other programme participants (including the Commission Services)	**X**
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

ENDURE   European Network for Durable Exploitation of crop protection strategies

UF   Utility function

Definitions

Summary

This documents aims at helping for the use of DEXiPM to assess current and innovative cropping systems proposed by the system case studies. This tutorial corresponds to a first prototype of DEXiPM that has been developed for the assessment of sustainability of arable crop cropping systems designed to limit the use of pesticides. The model will be improved according to feedback from system case studies. A joint document describing DEXiPM for arable crop systems is also available (DR2.14a). The tutorial was written by the designers of DEXiPM (INRA), but DEXiPM can be used by all partners of arable crop system case studies (maize and winter crop), and will be adapted to orchard systems. Details on inputs of the model and aggregation functions of assessment criteria of the model are given in appendices.

*Authors remind the users that **the model DEXiPM for arable crop systems is under development**. The prototype (DR2.14c) is made available together with its tutorial (DR2.14b) and with a description of the model (DR 2.14a). It will evolve according to feedback from arable crop system case studies and a new version of the model will be released at M42. **Authors ask the users to carefully report all their remarks** (criteria and hierarchy of criteria, choice of qualitative classes for criteria, utility functions, i.e. weights and aggregation rules, reports on assessments of systems) **and to send them to** Elise.Pelzer@grignon.inra.fr. DEXiPM will also be adapted to orchard systems.*

1. General points

DEXiPM has been implemented within the DEXi software that can be freely downloaded on the following website: http://www-ai.ijs.si/MarkoBohanec/dexi.html.

A tutorial of the software is available online at the following address: http://www-ai.ijs.si/MarkoBohanec/pub/DEXiManual30r.pdf.

DEXiPM is a **qualitative multi-attribute model** (or **multi-criteria model**): decision model allowing evaluation of option according to several and sometimes conflicting goals. A problem is decomposed into smaller and less complex problems, characterized by attributes (or criteria) that are organized hierarchically into a tree of attributes. A qualitative multi-attribute model consists of:

- **Attributes**: in DEXi, attributes are characterized by their name, a description, and a **scale**, *i.e.* possible qualitative values for the attribute (discrete values described as words rather than numbers). Attributes are rather **basic** (attributes that the user will describe when entering an option) or **aggregated** (resulting from an aggregation or utility function in DEXi, based on values of immediate descendant attributes). Identical or repeated attributes in the tree are **linked** in DEXi, and detailed only once if it is an aggregated attribute.

- **Utility functions**: utility functions (UF) determine the aggregation of attributes in the tree. They consist in "if-then rules" to fix the value of an aggregated attribute depending on the value of the immediate descendant attributes. UF are summarized by **weights** allocated to attributes. Rules of UF can either be fixed by the user, or automatically fixed by the software based on weights indicated by the user. Even if the DEXi software allows this automatic definition of rules, it is preferable to check this automatic attribution of rules before implementing the assessment.

The **option** is assessed, and is described by a vector of values of basic attributes. In the case of DEXiPM, an option is the cropping system and its crop protection strategy and its context. Most of the basic attributes for the description of the option in DEXiPM are at the cropping system scale: crop sequence for time, and group of fields for space. However, some basic (or aggregated) attributes deal with other levels, such as the landscape scale or the farm scale, and various time scales are explored with attributes, from short to long term assessment.

Six steps can be identified in the design and use of a qualitative multi-attribute model implemented in DEXi (Figure 1):

1. **Design of the model**: assessment criteria are chosen (characterised by their name, description and scale, 1bis), as well as their hierarchy in the tree and the rules for aggregation (UF).

2. **Adaptation of the utility functions** according to the context of assessment and to the user priorities.

3. **Input of options** (with eventually a feedback on scales of basic attributes, that can be modified if unsuitable)

4. **Evaluation**: estimation of qualitative values of criteria by DEXi, based on basic attributes entered, and on UF.

5. **Results analysis**: graphical output, evaluation options proposed by DEXi (with eventually a feedback on UF, that can be adjusted if unsuitable)

6. **Reports**
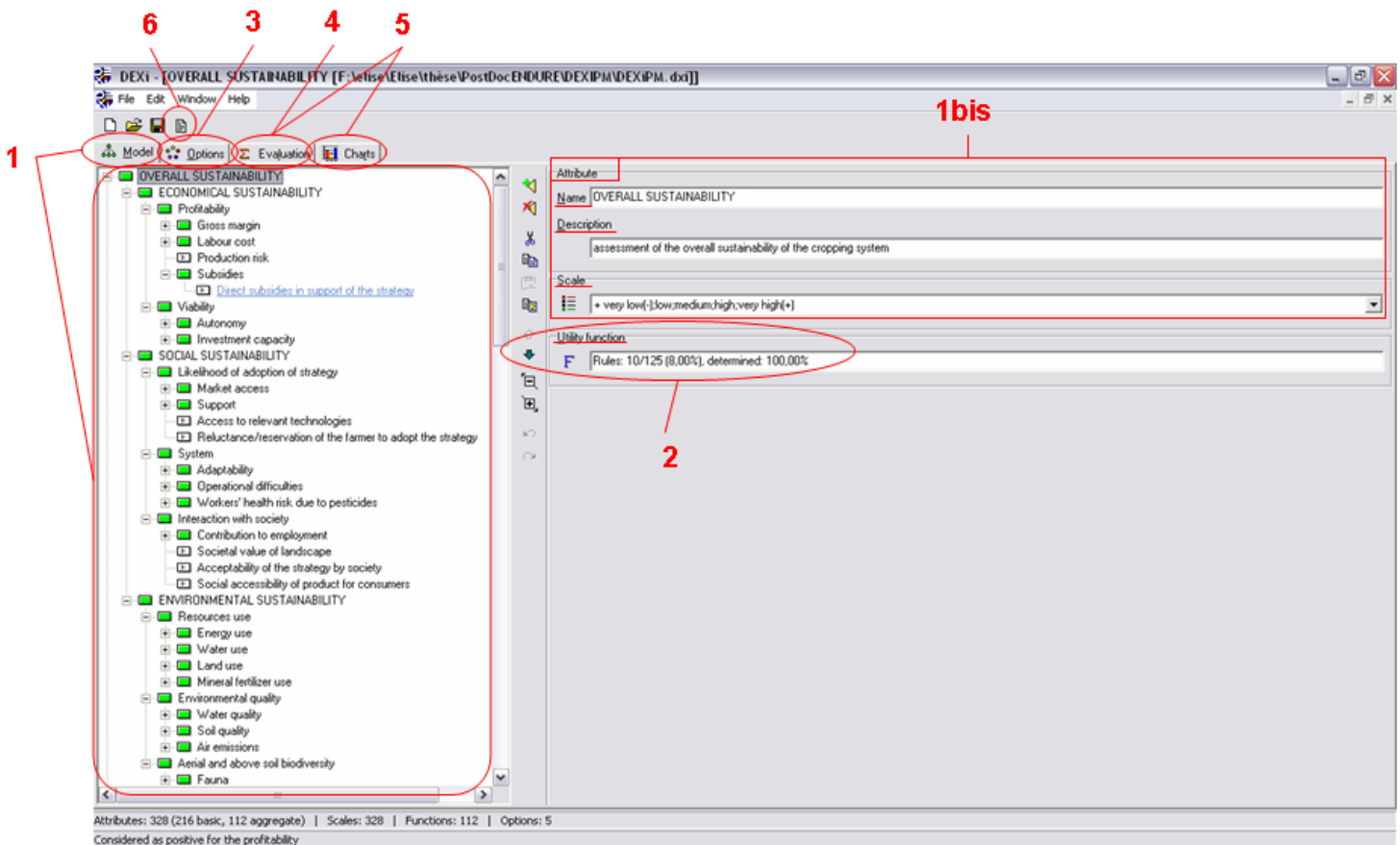
Figure 1. Presentation of the model page in DEXi, and selection of pages for the design and use of a DEXi model

2. Design of the model

This step consists in the design of the tree (choice and ranking of criteria) and in the choice of UF for aggregation.

For DEXiPM, the choice and ranking of criteria has been decided according to experts and existing evaluation methods such as INDIGO (Bockstaller and Girardin, 2008, Bockstaller et al., 2009), SALCA (e.g. Nemecek and Erzinger, 2005), MASC (Sadok et al. 2009), ECOGEN (Bohanec et al. 2008). The detailed description of DEXiPM is available in the deliverable.

Basic criteria are of three types (Appendix A):

- **Context inputs independent from the system** (*e.g.* climate)

- **Cropping system inputs**: all technical inputs that describe the system (crop sequence, pesticides, fertilisation, tillage…)

- **Context inputs dependent on the system** (*e.g.* relevance of advice, subsidies…)

Each utility function addresses a specific aspect of sustainability of a system. It determines the value of a criterion of sustainability at level n given the values of the descendant criteria at level n-1. In DEXiPM, UF are combinations of 2 to 5 criteria, taking 2 to 5 qualitative values (depending on the criterion).

UF are described by tables where the value of the aggregated criteria at level n is given for each combination of values of criteria at level n-1 (Figure 2). DEXi also proposed reports where UF are summarized (Figure 2). In theory, the user has a total freedom to fix the UF. However, recommendations are proposed for DEXiPM: some UF are fixed, according to quantitative data available in the literature, or scientific expertise, whereas others are adaptable according to priorities of the user or socio-economic, politic or pedo-climatic context (Appendix B). Limit thresholds for weights are also proposed. Except if there is a good justification, weights should not be equal to zero, as all criteria of the tree are important to consider when assessing the overall sustainability of the system, and if the weight of one criterion is null, it means that the whole ramification of the tree will be silenced, leading to a modification of the structure of the tree.

Figure 2. Utility functions in DEXi. DEXi proposes a summary of decision rules (red box): for example, in the first line, if "profitability" is very low, and if "viability" is low or less (very low), then the economical sustainability is very low.

More generally, all modifications (UF, classes…) in the model have to be reported carefully by the user and presented as part of the results of the evaluation. It is expected that in a coming version of DEXi , a window for such comment will be added to the software.

3. Adaptation of the utility functions according to the context of assessment and to the user priorities

Among the UF of DEXiPM, some are adaptable (Appendix B) according to the user priorities and/or to the context of the assessment, and need to be modified preliminary to the evaluation step. As mentioned above, the adaptation is not totally free, but minimum weights are proposed for each criterion (Appendix B).

Two methods are possible to assign UF to aggregated criteria: either the user fixes all the decision rules of the table or the user fixes the weights for criteria, and DEXi automatically fixes the decision rules according to these weights. The choice of one or the other method depends on the nature and sense of the criterion.

3.1. Method 1: all the decision rules are fixed by the user

The example of the criterion "selling price" is presented here. This criterion assesses the selling price of the production, depending on the average market price and on the valuation or devaluation of this price according to the crops of the crop succession (cash crops or not) and the respect of quality or certification requirements. The scale for average market price consists in four qualitative classes, whereas the one of valuation or devaluation of the price consists in three qualitative classes, leading to 4*3=12 decision rules to fix for the UF.

3.1.1. Step 1: selection of the utility function

Figure 3a. Selection of the utility function to be fixed

3.1.2. Step 2: definition of decision rules

In order to fix the decision rules, it is easier to place the more important criteria before the others, using the ⇧ and ⇩ buttons in the window displaying the tree (Figure 3a).

Figure 3b. Definition of decision rules

3.1.3. Step 3: displaying of obtained weights

It can be useful to visualise the weights obtained with the decision rules fixed, in order to see the importance of each criterion according to the decision rules chosen. This information is also available in the reports on UF proposed in the software (Figure 2).
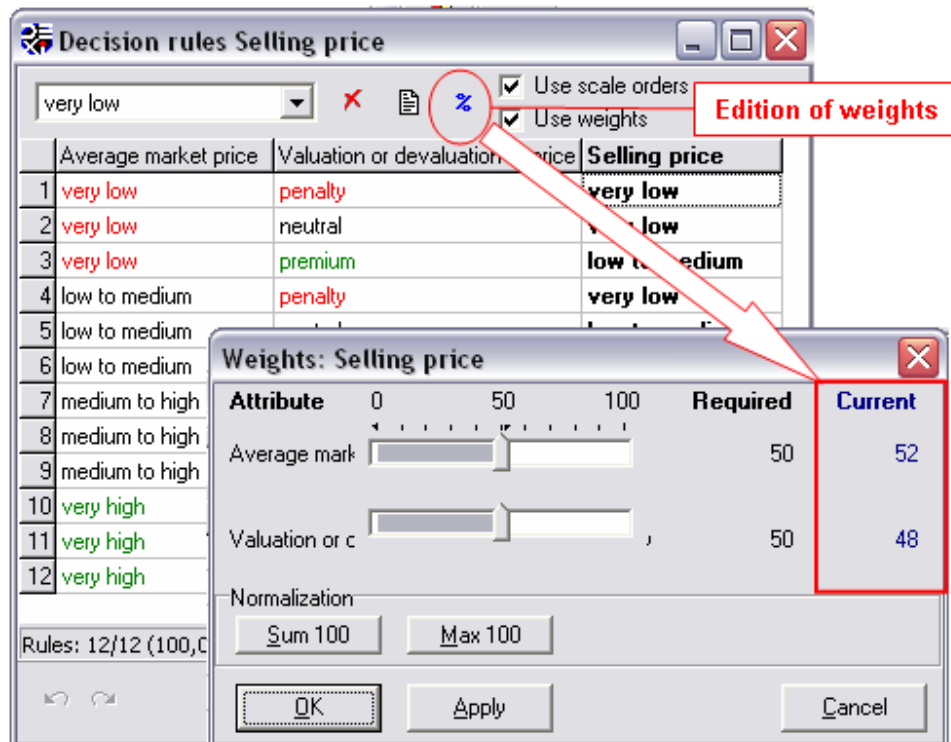
Figure 3c. Displaying of weights obtained after fixation of the decision rules

3.2. Method 2: weights are fixed by the user, and DEXi automatically fixes the rules by using these weights

The example of chemical soil quality is presented here, depending on organic matter and P fertility of the soil. The scale for organic matter consists in four qualitative classes, whereas the one of P fertility consists in three qualitative classes, leading to 4*3=12 decision rules to fix for the UF.

3.2.1. Step 1: selection of the utility function

This step is the same as before (Figure 3a).

3.2.2. Step 2: fixation of extreme values

In order to indicate the trend to the software, the first and last decision rules have to be fixed preliminary to the choice of weights.

Figure 4a. Fixation of extreme decision rules preliminary to the fixation of weights

3.2.3. Step 3: choice of weights and attribution of decision rules by DEXi

The user chooses weights for all criteria, here 60% for the organic matter and 40% for the soil fertility (Figure 4b). Decision rules are then attributed by DEXi based on these weights (Figure 4c).

Figure 4b. Choice of weights

Figure 4c. Establishment of rules by DEXi, based on weights given by the user.

3.2.4. Step 4: verification/modification of rules automatically attributed

This step is very important, as rules attributed automatically by DEXi are not always in accordance with the user/expert opinion. Each decision rule should be checked, or at least a significant number when the number of decision rules in the table is too high. A special care should be given to rules where a compensation can occur: e.g. if attribute 1 is "high" and attribute 2 is "low", it is relevant to ask whether the output "medium" is acceptable according to the goals or principle of sustainability. It should also be noticed that the modification of one rule can lead to automatic modifications of others by DEXi (according to the modification done by the user, Figure 4d), and to modification of weights assigned. This step should therefore be performed carefully.

Figure 4d. Verification of decision rules fixed by DEXi

4. Input of options

This step consists in giving a value to all basic attributes, describing the system and its context. Values of basic criteria are entered in the option tab. In addition to the description of attributes in DEXi, the table in Appendix A gives details on all basic attributes, as well as the correlation between attributes, and the scales of attributes. Basic attributes are classified as they are entered in DEXiPM.

- First, basic criteria for the description of the context, independent from the system: soil and climate, regional context and landscape, economical context and farm context. These criteria should be equal when comparing several systems.

- Second, basic criteria describing the system: crop sequence, pesticides treatments, fertilisation, tillage, irrigation, harvest, more global variables for the system description, and variables linked to the product.

- Third, basic criteria for the description of the context, dependent on the system: general, soil and climate, material, support, subsidies, production and product, farmer/societal judgment.

Some criteria are more difficult to estimates, and sheets are proposed to help the user to estimate the values of these more complex criteria. If the user has no idea about the estimation of one or several criterion, it is possible to leave a blank (* sign in DEXi), as DEXi is able to estimate qualitative value of aggregated criteria (at least to give a range of possible values) even if one or several basic criteria have no value.

When the user enters the option, he could find that scales of some basic attributes are not well adapted to the system he is describing. The class values or thresholds indicating limits between classes in a scale can be adapted by the user (Figure 5), but he will have to mention and justify this in the report of results. All UF involving criteria for which the scale has been modified should be checked: DEXi automatically modifies the UF when class values are modified, or when classes are added in the scale, without any explicit indications. The user has therefore to be careful when changing scales.
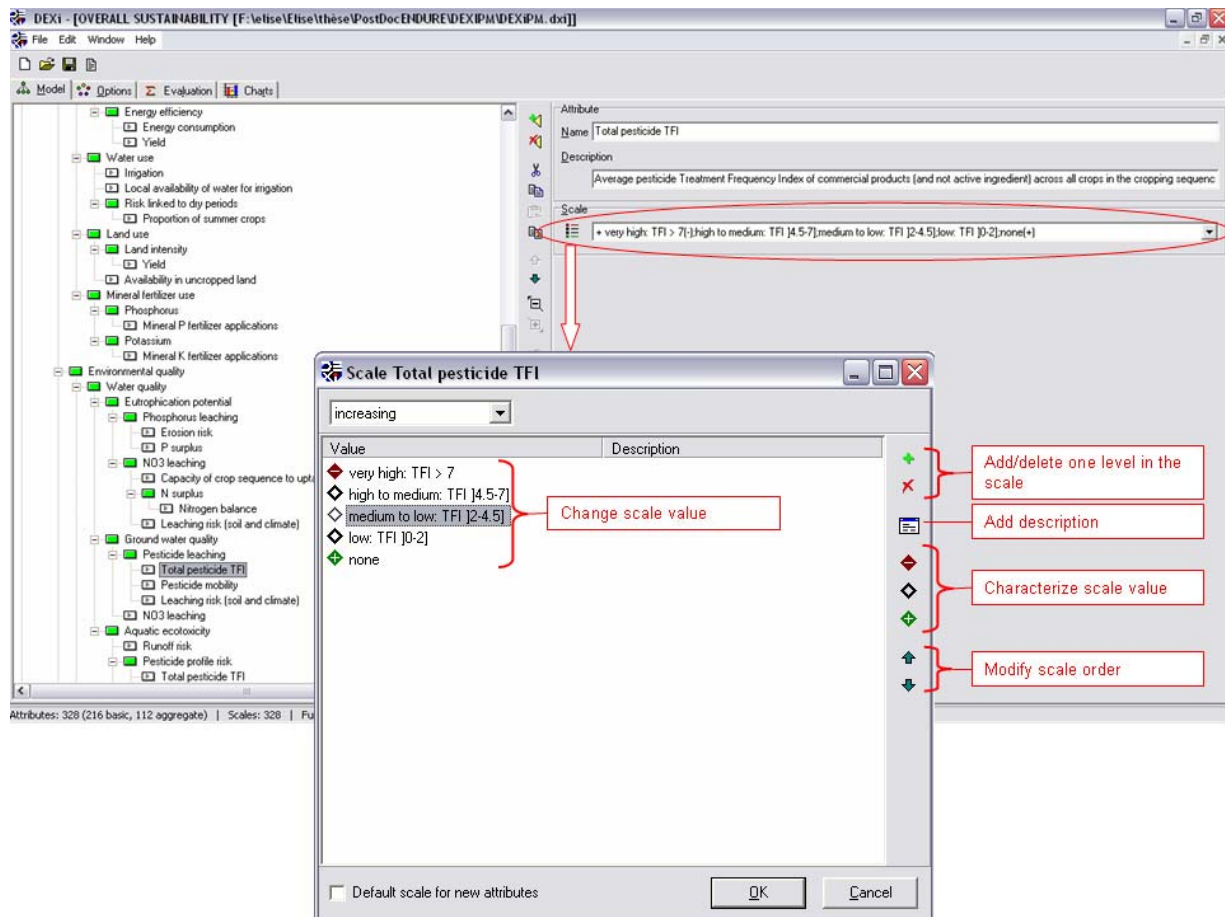
Figure 5. Modification of scales of qualitative classes

Sometimes, the user could have an estimation of aggregated criteria instead of basic one, *e.g.* when these attributes are not easily estimated in *ex ante* assessment, or when quantitative approaches allow the calculation of aggregated attributes in *ex post* assessment. The « pruning technique », *i.e.* the attribution of a value to aggregated attributes instead of to basic attributes, is not possible in the current version of the software, and would be difficult to implement (according the Bohanec, pers. com.) if DEXiPM is used for comparison of systems[1]. The only way to implement that is to delete the basic part of the tree below the aggregated criterion that is estimated, this criterion therefore becoming a basic attribute. This means that this new basic attribute will have to be estimated for all the compared options. It can be a problem when comparing current system with data allows calculation of some aggregated attributes and an innovative system with only qualitative data for basic attributes.

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[1] This option is possible to implement if DEXiPM is used to assess options independently (without comparison). This has been done with the ESQI model (http://kt.ijs.si/MarkoBohanec/ESQI/ESQI.php)

5. Evaluation

The evaluation consists in the estimation of all aggregated criteria based on the option represented by the vector of basic attributes, on the structure of the tree and on the UF for aggregation. It is run automatically by the software. Results of option evaluation (estimation of basic and aggregated attribute) are shown on the evaluation page, as well as on charts and corresponding report.

6. Results analysis:

6.1. Charts

On the charts page, it is possible to draw histogram and radar charts by selecting criteria that the user wants to see (Figure 6). Classes of criteria have been defined from the less to the more favourable to sustainability. For the graphical results reading, the more it is close to the centre of the radar, the less it is favourable to sustainability, and the more it is distant from the centre, the more it is favourable to sustainability. It is possible to show up to 4 option charts at the same time.
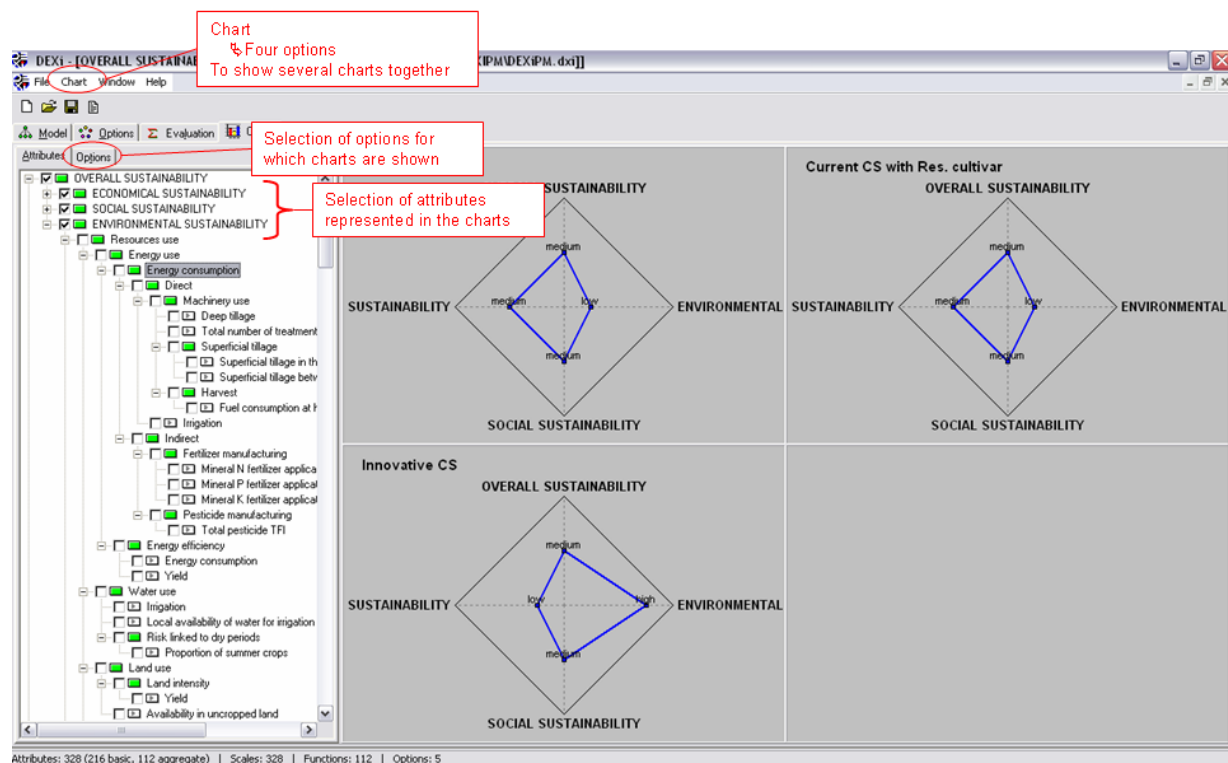
Figure 6. Edition of charts

The best way to analyse the results of an evaluation is to go step by step from the upper criteria to the more basic one. Firstly, the user can have a look to the overall sustainability and to the economical, environmental and social sustainability, and then go down each tree, in order to identify where the less understandable values of criteria are and what the explanation is.

Eventually, the user can modify some UF to adjust the results, always explicitly describing and justifying the modifications.

6.2. Other options

In the evaluation page, other options for results analyses are proposed.

The **"Plus-minus 1"** option investigates the effects of changing each basic attribute by one value down and up (if possible), independently of other attributes. The analysis is carried out for the currently selected option and displays the effects of changes on the currently selected aggregate attribute (Figure 7).
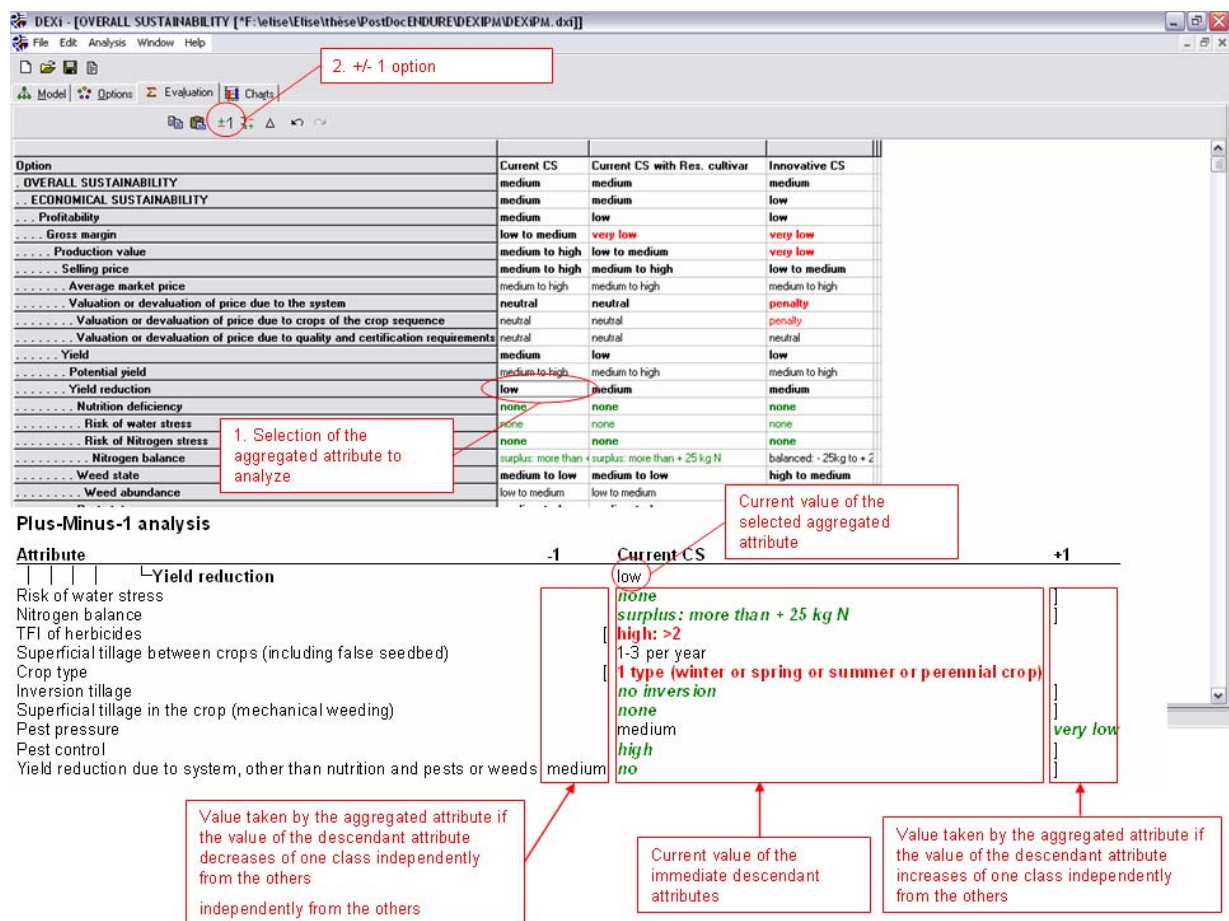
Figure 7. The" plus-minus 1" option. Here, the option says that if the pest pressure was low instead of medium, then the yield reduction will become very low (all other criteria keeping the same value), whereas if yield reduction due to system was medium instead of null (no), then the yield reduction will become medium. The variation of one class of all other basic criteria does not change the value of the aggregated criterion yield reduction.

The "**Selective explanation"** option displays extreme, *i.e.* stronger and weaker values of the currently selected option.

The **"compare"** option creates a report that is similar to the common *Evaluation results* report (see next part), but highlights differences between options, selected by the user. The primary

option values are displayed in full, whereas the secondary options values are displayed only when they differ from the primary option.

7. Reports

DEXi proposes to edit several reports that can be exported in pdf files:

- **Attribute tree**.

- **Scales** (and scale description): shows the tree and the scales of qualitative values for each attributes.

- **Rule tables**: presents the tables of summary of all utility functions.

- **Weights**: shows local and global weights of each attribute. The difference between *local* and *global* is due to the tree of attributes. *Local* weights always refer to a single aggregate attribute and a single corresponding utility function, so that the sum of weights of the attribute's immediate descendants (function arguments) is 100%. *Global* weights take into account the structure of the tree and relative importance of its sub-trees. A global weight of an attribute is calculated as a product of the local weight and the global weight of the attribute that lies one level above. A global weight of the root attribute is 100%. Weights can also be *normalized* or not. This is because some scales can have more values than the others. *Normalization* refers to the procedure in which all scales are adjusted to the same length before determining the weights. It is important to have a look to the global weights to estimate the sensitivity of the model to attributes. For instance, smaller branches of the tree (less levels of breaking down) may lead to higher global weights for basic attributes, and this has to be adjusted.

- **Evaluation and charts**: necessitate selecting options to be reported.

Figure 8. Report on local and global weights (not normalized), and highlighting of problem of sensibility of the overall tree to basic attributes

8. Example of description of systems for assessment

In order to help the user to describe options, three systems corresponding to winter crops based rotations are described in the current version of DEXiPM.

The three "winter crops" systems are described in the context of limestone plateau of region Bourgogne, with quite shallow soils. Environmental context inputs have been fixed according to the characteristics of this site. Economical or social context inputs independent from the system are equal for the three systems. The current system is a typical winter oilseed rape-winter wheat-winter barley rotation, with high amount of mineral fertilizers and pesticides, high sowing density, usual sowing date, and reduced tillage (no deep tillage). From this cropping system, we defined a second cropping system, with the wheat cultivar presenting resistance against aerial disease, but other crop management elements remaining the same. The third cropping system is more innovative. The rotation is longer: WOSR-winter wheat-spring barley-alfalfa-alfalfa-winter wheat-sunflower-triticale. No pesticide is used. The sowing density is lower than the current system. The sowing dates are adjusted to limit diseases (earlier sowing for WOSR, later sowing for wheat), and resistant cultivars are used. The quantity of N mineral fertilizers is low (no N on alfalfa), the quantity of P-K fertilizers is similar to the current system, as well as the tillage.

Some weights of the resource use utility function have been modified (compared with default value) to correspond to the regional context: weights of energy and land use are set at 40%, whereas weight of water use is lowered at 10% as water is not a problem in this region.

References

Bockstaller, C., 2007. Proposition de construction d'un modèle mixte pour l'évaluation des risques de ruissellement et d'érosion. Document de travail.

Bockstaller, C., Girardin, P., 2008. Mode de calcul des indicateurs agri-environnementaux de la méthode INDIGO.

Bockstaller, C., Guichard, L., Makowski, D., Aveline, A., Girardin, P., Plantureux, S., 2008. Agri-environmental indicators to assess cropping and farming systems. A review. Agronomy for Sustainable Development 28, 139-149.

Bohanec, M., Messean, A., Scatasta, S., Angevin, F., Griffiths, B., Krogh, P.H., Znidarsic, M., Dzeroski, S., 2008. A qualitative multi-attribute model for economic and ecological assessment of genetically modified crops. Ecological Modelling 215, 247-261.

Bonny, S., 1993. Is agriculture using more and more energy? A French case study. Agricultural Systems 43, 51-66.

Clements, D.R., Weise, S.F., Brown, R., Stonehouse, D.P., Hume, D.J., Swanton, C.J., 1995. Energy analysis of tillage and herbicide inputs in alternative weed management systems. Agriculture, Ecosystems & Environment 52, 119-128.

COMIFER, 2002. Lessivage des nitrates en systèmes de cultures annuelles. Diagnostic du risque et propositions de gestion de l'interculture. Rapport COMIFER, Groupe Azote.

CORPEN, 2006. Des indicateurs Azote pour gérer des actions de maîtrise de pollutions à l'échelle de la parcelle, de l'exploitation et du territoire. Rapport du Comité d'Orientation pour des Pratiques Agricoles Respectueuses de l'Environnement.

Fried, G., Norton, L.R., Reboud, X., 2008. Environmental and management factors determining weed species composition and diversity in France. Agriculture, Ecosystems & Environment 128, 68-76.

Levy, J.D., Bertin, M., Mazodier, J., Combes, B., Roux, A., 2005. Irrigation durable. Rapport du Conseil Général du Génie Rural, des Eaux et des Forêts.

Nemecek, T., Erzinger, S., 2005. Modelling representative life cycle inventories for Swiss arable crops. International Journal of Life Cycle Assessment 10, 68-76.

Nemecek, T., Richthofen, J.S.v., Dubois, G., Casta, P., Charles, R., Pahl, H., 2008. Environmental impacts of introducing grain legumes into European crop rotations. European Journal of Agronomy 28, 380-393.

Pervanchon, F., Bockstaller, C., Girardin, P., 2002. Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. Agricultural Systems 72, 149-172.

Sadok, W., Angevin, F., Bergez, J.E., Bockstaller, C., Colomb, B., Guichard, L., Reau, R., Messéan, A., Doré, T., 2009. MASC: a qualitative multi-attribute decision model for ex ante assessment of the sustainability of cropping systems. Agronomy for Sustainable Development In press.

Taureau, J.C., Gitton, C., Laurent, F., Machet, J.M., Plas, D., 1996. Calcul de la fertilisation azotée des cultures annuelles. Rapport COMIFER, Paris, 59 p.

Appendices

Appendix A: List and description of input/basic attributes of DEXiPM.

Inputs	Corresponding pillar	Short description and observations (correlation with other inputs)	Qualitative classes[2]
Context inputs independent from the system (fixed in the case of comparison of systems)			
Soil and climate			
Leaching risk (soil and climate)	Environment	Effect of soil type and depth, climate, etc. on the risk of leaching. This may be estimated by the drainage indicator (rain during leaching period/soil water stock, CORPEN)	very high, high to medium, medium to low, very low *See attached sheet 1*
Runoff risk due to context	Environment	Surface runoff is considered water, from rain, snowmelt, or other sources, that flows over the land surface. It can pick up contaminants such as pesticides, or fertilizers. Another source not considered here is runoff due to water saturation of the soil profile. The amount of soil that can be lost due to runoff is considered in the following criterion Field erosion. It is linked to topographical risk (increases with the slope and with the slope length). Soil cover and effect of tillage are considered in other criteria.	high, medium, low
Field erosion risk due to context	Environment	Amount of soil lost from a field by runoff due to the action of rain drops on soil (In this context, it does not include soil losses due to wind erosion). It is linked to topographical risk (increases with the slope and with the slope length). Soil cover and effect of tillage are considered in other criteria. **Correlation with runoff risk due to context (low if runoff risk due to context is low)**	high, medium, low
Hydromorphic soil	Environment	A general term for soil state that develops under conditions of poor drainage, such as marshes, swamps, seepage areas and flats (clay soils are more hydromorphic than sandy soils). Hydromorphic soils are sources of denitrification (N_2O emissions). Well drained soils are not Hydromorphic.	yes, no
Potential yield	Economic	Overall assessment or the potential yield of all the crops of the crop sequence. It is important to note that potential yields should be estimated <u>independently from the system</u>. They mostly depend on pedoclimatic conditions	very low, low to medium, medium to high, very high
Regional context and landscape			
Regional intensification	Environment	Estimation of intensification at the regional scale. This criterion helps to estimate flora diversity. The proportion of non-cropped area in the region should be taken into account, as well as intensity of practices in fields of the region. The landscape does not favour biodiversity if it is	Not favourable to biodiversity, favourable to biodiversity

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[2] Qualitative classes are proposals and can be modified if they are not adapted to the context (country) of assessment

mainly an open-field area, whereas it favours biodiversity if fields are at least partly surrounded or included in mixed-cropping–breeding systems that include hedges and both arable fields and meadows (French name '*bocage*'; Fried et al. 2008)

Availability of uncropped land	Environment	Relative amount of <u>uncropped land, not used for agricultural production</u>. This criterion assesses the fact that extensive systems will require more land area to produce the same amount (population growth context), and land availability is a problem in most of the European regions	very low, low to medium, medium to high, very high
Non-productive areas	Environment	Proportion and connectivity of <u>non-cropped areas adjacent to the fields</u> (contrary to the previous attribute that deals with uncropped area in the region, not field border): hedges, field margins, etc. This criterion is used to estimate flora and fauna biodiversity.	low proportion, medium proportion but low connectivity, medium proportion and high connectivity, high proportion and connectivity
Economical context			
Average market price	Economic	Relative commodity price. This criterion assesses the market condition for agricultural production, independently from the type of crops (effect of cash crops in the crop sequence is estimated in the criterion "Valuation or devaluation of price due to crops in the crop sequence") and from subsidies. This criterion highly depends on the country and it could raise problems when comparing countries.	very low, low to medium, medium to high, very high
Labour hourly wage	Economic	Level of wages for employees, used to estimate the cost of labour. The case of double employment is not explicitly taken into account neither for this criterion nor for the criterion number of hours.	very high, high to medium, medium to low, very low
Farm context			
Local availability of water for irrigation	Environment	Depends on availability of water (ground water availability, proximity of a river, water cisterns, restriction regulations, etc.) and on restriction frequency imposed by regulation	Low (restriction every year), medium (restriction 1/2 or 1/3 year), high (no restriction)
Financial security of the farm	Economic	Availability of <u>financial resources for investment</u> necessary for the cropping system, for example new tillage material for mechanical weeding, specific harvesters, etc.	low, medium, high
System inputs (crop sequence, crop management on each crop and between crops)			
Crop sequence			
Number of crops	Social	Number of different crops in the cropping sequence, including intermediate catch crops. This criterion is <u>only used in social sustainability</u> to estimate the complexity of the CS, not only in terms of techniques linked with the number of different crops, but also in terms of complexity linked with pest attacks. The more crops, the more complex, with the exception of monoculture, that is supposed more complex because of consequences in terms complexity linked with risk of pests, risk of soil structure damaging, risk of fertility loss, etc.	high (5 or more) or monoculture, medium to low (2-4)
Proportion of autumn-harvest crops	Environment	Crops that remains in field during the driest months (July-August), harvested after the end of September: sugarbeets, maize etc.	very high [75-100%], high to medium [50-75%[, medium to

				low [25-50%[, very low [0-25%[
		Correlation with "crop type"		
Crop type	Environment	Variety of crops in the crop sequence (in terms of sowing season): winter crops, spring crops, summer crops or perennial crops		1 type (winter or spring or summer or perennial crop), 2 types, 3 types, 4 types (winter and spring and summer and perennial crop)
Crop effect on pollinators	Environment	Proportion of crops suitable for pollination (nectar plants). Wheat, barley, maize and most cereals are not attractive, oilseed rape, sunflower, pea or alfalfa, for example, are more attractive. Intermediate catch crops have to be considered for the estimation of this attribute.		not favourable, little favourable, favourable, very favourable
Additional seed cost of crop species or cultivars[3]	Economic	Additional seed cost linked to the crop species and cultivars grown (*e.g.* resistant cultivar), independently from the sowing density. Seed treatments can also be considered if it has a significant impact on the price. Intermediate catch crops have to be considered for the estimation of this attribute. **Correlation with "TFI fungicide"**		high, moderate, no
Sowing density	Economic	Assessment of the sowing density for all crops of the crop sequence. Estimation of density (high, medium or low) highly depends on the region of assessment: soil type and climate (frost risk) leading to seedling death. Sowing density should be in accordance with sowing date: higher density when early or late sowing, because of higher risk of seedling losses.		high, medium, low ***See attached sheet 2***
Soil cover	Environment	Typical crop cover, average for the crops of the crop sequence, taking into account all crops in the crop sequence, as well as intercrop periods (bare soil, volunteers or intermediate catch crop). *The classes for this attribute could not be relevant some countries and can be adapted if necessary.* **Correlation with "proportion of summer crops", "crop type", "proportion of autumn-harvest crops", "soil cover at pesticide application"**		low (0-40%), medium (41-60%), high (61-100%) ***See attached sheet 3***
Pesticide treatments				
TFI of insecticide	Environment	Average insecticide Treatment Frequency Index of commercial products (and not active ingredient) across all crops in the cropping sequence $$TFI = \frac{1}{n}\sum_{t=1}^{t=T_I} \frac{DI_t}{DAp_t}$$ with n: number of years in the crop sequence, T_I: total number of insecticide treatments, DI: applied dose in commercial product, DAp: approved/registered dose for the commercial product		High (>2), medium (]1-2]), low (]0-1], none
TFI of fungicide	Environment	Average fungicide Treatment Frequency Index of commercial products (and not active ingredient) across all crops in the cropping sequence		High (>2), medium (]1-2]), low (]0-1], none

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[3] The origin of seeds is not considered in the seed cost whereas seeds that are produced in the farm (particularly in organic systems) are less expensive. This could be added in a future version of DEXiPM

		$$TFI = \frac{1}{n}\sum_{t=1}^{t=T_F}\frac{DF_t}{DAp_t}$$ with n: number of years in the crop sequence, T_F: total number of fungicide treatments, DF: applied dose in commercial product, DAp: approved/registered dose for the commercial product **Correlation with "Additional seed cost of cultivar" (if use of resistant cultivar)**	
TFI of herbicide	Environment	Average herbicide Treatment Frequency Index of commercial products (and not active ingredient) across all crops in the cropping sequence $$TFI = \frac{1}{n}\sum_{t=1}^{t=T_H}\frac{DH_t}{DAp_t}$$ with n: number of years in the crop sequence, T_H: total number of herbicide treatments, DH: applied dose in commercial product, DAp: approved/registered dose for the commercial product. For herbicides, the proportion of treated surface per field could be included in the calculation of the indicator to take into account localised treatments (*e.g.* on rows)	High (>2), medium (]1-2]), low (]0-1], none
Total Pesticide TFI	Economic, social, environment	Average pesticide Treatment Frequency Index of commercial products (and not active ingredient) across all crops in the cropping sequence, for fungicides, insecticides, herbicides, molluscicides, growth regulators and all other products used $$TFI = \frac{1}{n}\sum_{t=1}^{t=T}\frac{D_t}{DAp_t}$$ with n: number of years in the crop sequence, T: total number of pesticide treatments, D: applied dose in commercial product, DAp: approved/registered dose for the commercial product. Seed treatments are not taken into account as their impact compared to sprayed pesticides is not clear. *The classes for this attribute could not be relevant some countries and can be adapted if necessary.* **Correlation with "TFI fungicide", "TFI insecticide", TFI herbicide"**	Very high (>7), high to medium (]4.5-7]), medium to low (]2-4.5]), low (]0-2], none
Pesticide mobility	Environment	Pesticide mobility is taken into account to assess the risk of pesticides reaching water. Mobility depends on the plant protection product family. This can be estimated using the Ground water Ubiquity Score (GUS). In this case, across the crop sequence, a "worst case" can be applied, *i.e.* the most mobile pesticide has to be used to estimate the attribute.	High, medium, low, no pesticide *See attached sheet 4*
Pesticide eco-toxicity	Environment	Environmental toxicity of products depending on the active ingredients. In this case, across the crop sequence, a "worst case" can be applied, *i.e.* the most toxic pesticide has to be used to estimate the attribute	High, medium, low, no pesticide *See attached sheet 4*
Soil cover at pesticide application	Environment	The proportion of soil covered for the most risky pesticide application (see pesticide mobility and pesticide eco-toxicity attributes), often herbicide. **Correlation with "soil cover"**	Low (0-20%), medium (21-60%), high (61-100%) or no application *See attached sheet 3*

Fertilisation			
Mineral N fertilizer applications	Economic, environment	Average amount of mineral N applied per year. The form (liquid or not) impacts volatilization of NH_3 (no evidence for N_2O)	High (> 150 kg/ha), medium (50-150 kg/ha), low (0-50 kg/ha), none
Organic N fertilizer applications[4]	Environment	Average per year. The form (liquid or not) impacts volatilization of NH_3 (no evidence for N_2O) **Correlation with "Organic amendments"**	liquid manure or hen droppings, solid manure or low amount of liquid manure/hen droppings, compost or low amount of solid manure, none
Organic amendments[4]	Environment	Average amount of organic amendments per year. **Correlation with "Organic N fertilizer applications"**	liquid manure or low amount of hen droppings, hen droppings or low amount of solid manure, solid manure or low amount of compost, compost
Coverage of crop Nitrogen requirement	Economic, Environment	Should take into account the amount of N fertilizers, the requirement of the crop and the yield. A deficiency could be tolerated for some reasons, or occur because of a miscalculation of the doses supplied, whereas a surplus could occur for example in a situation where high protein content is required. **Correlation with "Mineral N fertilizer applications", "Organic N fertilizer applications", "yield"**	Deficiency: less than – 25 kg N, balanced: - 25 to + 25 kg N, surplus: more than + 25 kg N *See attached sheet 5*
Mineral P fertilizer applications	Economic, environment	Average amount per year, expressed in P_2O_5. For information, 100 kg/ha of P_2O_5 = 44 kg/ha of P	High (> 100 kg/ha P_2O_5), medium (50-100 kg/ha), low (0-50 kg/ha), none
P surplus	Environment	Should take into account the amount of P fertilizers, the requirement of the crop, soil type, etc. **Correlation with "Mineral P fertilizer applications"**	high, medium, low, none
Mineral K fertilizer applications	Economic, environment	Average amount per year, expressed in K_2O. For information, 100 kg/ha of K_2O = 83 kg/ha of K	High (> 100 kg/ha K_2O), medium (50-100 kg/ha), low (0-50 kg/ha), none
Total number of treatment operations	Economic, environment	The summed number of applications made per year. This should take into account all pesticides and fertilizers. The lower class (3 or less per year) could correspond to a system with 0 pesticide and low amount of fertilizers (eventually crops without fertilizers, such as pluri-annual crops integrated for several years in the crop sequence). **Correlation with "Mineral N, P, K fertilizer applications", "Organic N fertilizer applications", "Total pesticide TFI"**	7 or more per year, [4-7[per year, less than 4 per year
Tillage			

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[4] The amount of organic N should be taken into account, particularly if organic systems are assessed. This could be added in a future version of DEXiPM

Deep tillage[5]	Economic, environment	Frequency of deep tillage (with or without inversion) in the rotation. **Correlation with "Inversion tillage"**	Every year, 1 year out of two (or more), less than ½ year, no
Inversion tillage[5]	Environment	With or without inversion. This criterion is used to estimate weed abundance. The inversion has a great impact on weed abundance, whereas a deep tillage without inversion will have less of an impact. **Correlation with "Deep tillage"**	With inversion, no inversion[5]
Superficial tillage in the crop (mechanical weeding) [5]	Economic, environment	Average number of operations per year (combined tools should be counted several times).	2 or more per year, [1, 2[per year, [0, 1[per year
Superficial tillage between crops (including false seedbed) [5]	Economic, environment	Average number of operations per year (combined tools should be counted several times)/	5 or more per year, [1, 5[per year, [0, 1[per year
Irrigation			
Irrigation	Economic, environment	Amount of water used for the entire crop sequence, average per year. **Correlation with "crop type", "Proportion of summer crops"**	high, medium, low, none
Risk of water stress	Economic	Depends on rain, soil, crops requirements, irrigation. **Correlation with "crop type", "Proportion of summer crops", "Irrigation"**	High, medium, low, none
Harvest			
Fuel consumption at harvest	Economic, environment	Average consumption depending on the harvest tools for crops of the crop sequence (*e.g.* sugarbeet harvester consumes more than cereal harvester). Other fuel consumptions (tillage, fertilizers and pesticides applications) are estimated through other criteria.	High, medium, low
Stubble/straw management	Environment	This criterion impacts soil organic matter. The consequence of burnt stubble/straw is the same, in terms of organic matter, as exported stubble/straw	Exported or burnt, not exported
Global variables for the system description			
Capacity of crop sequence to uptake N during the leaching period	Environment	Leaching is mainly confined to autumn and winter. Depends on the frequency of bare soil periods, the occurrence of catch crops, the occurrence and nature of volunteers, and also on the duration of non-uptake period (sometimes starting before harvest of the previous crop and ending after emergence of the following crop). The effect of stubble (date of stubble breaking, C/N ratio) is secondary but can be taken into account. **Correlation with "crop type", "soil cover", "Stubble/straw management"**	very high, high to medium, medium to low, very low ***See attached sheet 6***
Yield reduction due to system, other than	Economic	Yield reduction may be due to resistant cultivars, delaying of sowing dates, lower yield targets, etc. This has to be estimated relative to current systems, with highly productive cultivars, sown	High, medium, no

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[5] Minimum tillage systems are considered by the estimation of the three criteria deep tillage (that should be none, superficial tillage between crops and superficial tillage in the crop

nutrition and pests or weeds[6]		at usual dates.	
Habitat management	Environment	Sowing and spatial arrangement of adjacent newly non-cropped areas, leading to a higher proportion and better connectivity of non-productive areas.	none, low increase of % of non-productive areas, low increase of % and increase of connectivity, high increase of % and connectivity
Habitat management quality	Environment	Characterizes the type of species sown on newly non-cropped areas. None, if there is no habitat management. **Correlation with "habitat management"**	none, little favourable to flora, favourable to flora, very favourable
Pest control	Economic	This criterion summarizes all control methods, chemical and other, and should therefore be in accordance with other criteria describing the system. Even if it is redundant with other input criteria, it has to be estimated. **Correlation with all criteria impacting pest control: crop sequence, cultivars, TFI, N fertilizers, sowing density, etc.**	none, low, medium, high
Number of hours	Economic, social	Estimation of time necessary for all operations of the cropping system. Includes monitoring time, such as 'in the field crop surveillance', necessary for the protection strategy. Average per year for the entire crop sequence. **Correlation with all criteria describing practices**	very high, high to medium, medium to low, very low
Risk of simultaneous operations, due to a limited number of suitable days	Social	Concurrence in timing of operations, during some periods of the year, often due to diversification of crop sequence or practices. **Correlation with all criteria describing practices**	high, medium, low
Physical difficulty and disturbance	Social	Noise, repetition of a task, etc. for example, superficial tillage for mechanical weeding can be estimated as highly difficult (more generally, for tillage, the difficulty depends on the machinery and tool used). **Correlation with all criteria describing practices**	high, medium, low
Heavy metal contamination	Environment	Environmental quality. There is almost no risk of contamination in arable crop systems, except when slurry, sewage sludge or compost are supplied (more risks occur in vineyard systems when copper is applied). **Correlation with "Organic and mineral N fertilizer applications", "Organic amendment"**	high, medium to low, none
Product			
Proportion of gross margin due to main crop	Economic, social	Does the system economically rely on one or several crops of the crop sequence? (Specialization of the system). The main crop is the one that has the highest selling price per	high: >50% of margin relying on the main crop(s), medium: 25-

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[6] The possible yield increase that could be associated with some practices (e.g. maize GM cultivars present higher yields) is not taken into account in DEXiPM and could be added in future versions

			50% of margin relying on the main crop(s), low: <25% of margin relying on the main crop(s)
Risk of pesticide residuals in product	Social	Indicates the quality of production, in terms of pesticide contamination. This risk depends on the crops of the crop sequence (*e.g.* for maize, except for sweet corn, there is no late pesticide application and therefore no risk) but has to be estimated at the crop sequence scale. **Correlation with "Total pesticide TFI"**	Above the regulation threshold, below the regulation threshold, none
Risk of mycotoxin contamination	Social	Indicates the quality of production, in terms of mycotoxin contamination	Above the regulation threshold, below the regulation threshold, none
Context inputs dependent on the system (inputs linked to the context but that vary depending on the system)			
General			
Production risk	Economic	Uncertainty of yield. Overall assessment of the risk (climate, high pest attack, etc.)	high, medium, low
Soil and climate			
Pest pressure	Economic	Due to the pedo-climatic context and the system. Should take into account the effect of spatial distribution of crops/practices	high, medium, low, none
Quantity of rain during late harvest	Environment	For the estimation of risk of soil compaction. Concerns above all autumn harvests. **Correlation with "proportion of autumn-harvest crops"**	very high, high to medium, medium to low, very low
Material			
Requirement for agricultural equipment	Economic	Requirement for specific equipment needed by the farm for the system assessed (*e.g.* equipment for mechanical weeding, harvester if a new crop is included in the crop sequence, etc.). For current systems, requirement for specific equipment will be low-none. **Correlation with all criteria describing practices needing equipment**	high, medium, low-none
Risk of pesticide drift due to material	Environment	The risk of pesticide drift depends on the material as well as on the wind, but the weather (wind) should not be considered here. The risk of pesticide drift remains therefore low in arable crop systems as the material is safer than in orchards or vineyards.	high, medium, low
Support			
Farmer and employees knowledge and skills	Social	Estimation of the management capacity and skills of farmers and their employees to apply the strategy. Depends on both the educational level of the farmer and his/her ability to seek out appropriate advice. Innovative systems will be more easily adopted by farmers with high (or medium) skills. The level of permanent work should be considered in orchard systems, as farmers have often several activities and do not work full time on orchard (decreases skills).	low, medium, high
Affiliation to a farm support network	Social	Farmers groups, etc… For "good" support to be provided, the network has to be familiar with the strategy	no network or no affiliation to a network corresponding to the strategy, affiliation to a network

			corresponding to the strategy
Availability of relevant advice for the strategy	Social	An indication of availability of relevant advice to help the farmer to adopt strategy: advice adapted to the strategy and independent from input selling. The independency of advisors (independency for the type of system, and for the input selling) should therefore be taken into account (as well as the specialization of advice for orchards systems).	No, low to medium, high
Subsidies			
Environmentally based direct subsidies in support of the strategy	Economic	Direct subsidies based on environmental aspects of the system. Corresponds approximately to the second pillar of CAP. **Correlation with "habitat management", "non-productive area"…**	high, medium, low, none
Non-environmentally based direct subsidies in support of the strategy	Economic	Direct subsidies based on non-environmental aspects of the system. Corresponds approximately to the first pillar of CAP	high, medium, low, none
Production and product			
Access to relevant technologies	Social	This criterion includes financial and geographical (proximity) access to technologies necessary to adopt the innovative system (*e.g.* seeds, specific equipment, etc.) **Correlation with "Additional seed cost of crop species or cultivars"**	very limited, limited, possible, easy
Delivery constraints	Social	Reliance on off-farm enterprises or collecting firms to sell the production (*e.g.* alfalfa crop can be sold only if there is cattle livestock at proximity of the farm)	high, medium, low, none
Compatibility with quality requirements other than health	Social	The compatibility could decrease because of the adopted strategy, leading to non-respect of requirements. For arable crops, quality other than health can be protein contents, dry matter level, etc. Aesthetical for orchards. Depends on the distribution network. Risk for health (mycotoxins, pesticide residuals) is considered elsewhere.	Low to no, medium, high or no technological/esthetical requirement
Compatibility with certification requirements	Social	Non-compliance with requirements due to the adopted strategy could occur (*e.g.* because of the cultivar)	Low to no, medium, high or no certification requirement
Valuation or devaluation of price due to crops in the crop sequence	Economic	Proportion of cash crops in the crop sequence. If the current system has one or several cash crops (such as onions), the criterion can be estimated at premium. For alternative systems, the user should estimate how this proportion evolves in comparison with current system (more/less cash crops). This attribute is difficult to estimate as it is estimated relatively to other systems. Be sure when comparing systems that the estimations are correct between systems, the current system being fixed at neutral if there is no specific cash crop.	penalty, neutral, premium
Valuation or devaluation of price due to quality and certification requirements	Economic	Devaluation due to lost quality or certification requirements, valuation due to certification of the adopted strategy (IPM). The estimation of this criterion for current systems depends on the occurrence of a certification of one or several crops of the crop sequence (neutral if no certification, premium if certification with the hypothesis that requirements are satisfied). For alternative systems, the user should estimate how it evolves in comparison with current system (neutral if no certification). This attribute is difficult to estimate as it is estimated relatively to	penalty, neutral, premium

		other systems. Be sure when comparing systems that the estimations are correct between systems, the current system being fixed at neutral if there is no specific quality specificity. **Correlation with "Compatibility with technological/aesthetical requirements", "Compatibility with certification requirements"**	
Farmer/societal judgment			
Reluctance/reservation of the farmer to adopt the strategy	Social	Can be due to risk of yield decrease, non-possibility of product selling (downgrading of harvest), etc. for current system, the criterion is "none". **Correlation with "yield", "complexity", "production risk"**	Yes, none
Social accessibility of product for consumers	Social	How the system could prevent the accessibility to product for part of the society (too high prices for example). In the current context, there is no problem of accessibility for products cultivated intensively/conventionally (criterion is "accessible" for current system) **Correlation with "production cost" and "production value"**	little accessible, accessible
Societal value of landscape	Social	How the system improves or degrades the perception of the landscape by the society: diversity of crops, colours, unusual crop in a given region, non-productive areas, 3-dimension perception etc. This criterion is highly subjective but interesting to keep in mind when assessing overall sustainability of cropping systems. The estimation for current systems is bad (*e.g.* monocrops) or indifferent. **Correlation with "crop type", non-productive areas", "habitat management", etc.**	bad, indifferent, good
Acceptability of the strategy by society	Social	Acceptability of product and production mode by the society (*e.g.* GM crops). For example, the acceptability of a current system with high amount of pesticides and fertilizers can be considered as low.	low, indifferent, acceptable

Appendix B: Summary of utility functions

Criteria	Rules	Weights	Proportion of fixed rules in the UF[7]
OVERALL SUSTAINABILITY	**Adaptable** According to user's priorities. If one out of three contributing attribute (social, economical or environmental) is low or very low, the overall sustainability can not be high or very high Minimum15% per criterion	Equal by default (social, economy, environment)	46/125
ECONOMICAL SUSTAINABILITY	**Adaptable** According to user's priorities Minimum 30% per criterion	Equal by default (profitability and viability)	4/25
Profitability	**Adaptable** Gross margin very low: profitability low or very low Minimum 20% for gross margin, 10% for other criteria	By default 40% gross margin, 20% production risk, 20% labour cost, 20% direct subsidies.	6/144
Gross margin	**Fixed** Resulting from simulations with 4 realistic values of production value and production cost, corresponding to the four qualitative classes of both criteria.	Leading to 60% production value, 40% production cost	10/16
Production value	**Fixed** by the designers	50% selling price 50% yield	20/20
Selling price	**Fixed** Based on the average market price. Unchanged if there is no valuation or devaluation, a penalty decreases the price of one class, a premium increases the price of one class.	Leading to 50% average market price, 50% valuation or devaluation	12/12
Valuation or devaluation of price due to the system	**Fixed** Penalty decreased of one class, premium increase of one class, neutral: no effect	Leading to equal weight for each criterion (Valuation or devaluation of price due to crops of the crop sequence, and due to quality and certification requirements)	9/9
Yield	**Fixed** Potential yield very low: yield very low Other cases:	Leading to 50% potential yield, 50% yield reduction	20/20

[7] This is a good indicator to see if decision rules are mostly fixed by the designer or user, or if they are automatically fixed by DEXi based on weights entered by the designer/user

	Yield has the same value of the potential yield for low or very low yield reduction Yield decreased of one class if yield reduction is high, of two classes if yield reduction is very high.		
Yield reduction	**Fixed** Based on Bohanec et al. 2008, adapted by designers of DEXiPM	45% yield reduction due to system, other than nutrition and pests or weeds 25% nutrition deficiency 15% pest state 15% weed state	23/192
Nutrition deficiency	**Fixed** N mineral nutrition is not taken into account when the water stress is high or medium	60% risk of water stress 40% risk of Nitrogen stress	8/8
Pest state	**Fixed** Very low when no pressure Low (no or low control) or very low (control high and very high) when pressure low	70% pest pressure 30% pest control	7/16
Production cost	**Fixed** Based on systems described in the French ADAR project "systèmes innovants", on AGRESTE 2006 survey, on data from a French farm in region Centre, and on Levy et al. 2005	27% pesticides 27% fertilizers 18% fuel 18% seeds 10% irrigation	8/768
Cost of fuel	**Fixed** Based on Clements et al. 1995, for energy	15% deep tillage 30% superficial tillage 30% total number of treatment operations 25% fuel consumption at harvest	108/108
Cost of fertilizers	**Fixed** Based on Bonny, 1993, for energy	70% Mineral N fertilizers application 15% Mineral P and K fertilizers application	6/64
Cost of seeds	**Fixed** by the designers	50% Additional seed cost of crop species or cultivars 50% Sowing density	4/9
Labour cost	**Fixed** by the designers	50% number of hours 50% cost per hour	4/16
Direct subsidies in support of the strategy	**Adaptable** Based on user's priorities Minimum 20% per criterion	By default, 50% Environmentally based direct subsidies in support of the strategy, 50% Non-environmentally based direct subsidies in support of the strategy	16/16
Viability	**Adaptable** According to user's priorities Minimum 30% per criterion	By default 50% autonomy, 50% investment capacity	9/9

Autonomy	**Adaptable** According to user's priorities Minimum 10% per criterion	Equal by default (pesticide dependency, economic efficiency, economic independency, specialization)	10/81
Economic independency	**Fixed** by the designers	60% direct subsidies 40% gross margin	5/12
Economic efficiency	**Fixed** by the designers	60% gross margin 40% production value	16/16
Pesticide dependency	**Fixed** by the designers	60% pesticide cost 40% production value	12/16
Investment capacity	**Fixed** by the designers	50% requirement for agricultural equipment 50% Financial security of the farm	4/9
SOCIAL SUSTAINABILITY	**Adaptable** According to user's priorities Minimum 20% for likelihood of adoption and system.	By default, 45% likelihood of adoption and system, 10% interaction with society	8/125
Likelihood of adoption	**Adaptable** According to politic/socio-economic context Minimum 10% per criterion	By default, 45% market access, 30% support, 15% access to technologies, 10% reluctance/reservation of the farmer	17/36
Market access	**Adaptable** According to politic/socio-economic context Minimum 20% product quality compliance with health requirements, other can be null	By default, 30% delivery constraints, 25% product quality compliance with health requirements, 25% compatibility with aesthetical/technological requirements, 20% compatibility with certification constraints	30/144
Product quality compliance with health requirements	**Fixed** by the designers	50% risk of pesticide residuals in product 50% risk of mycotoxin contaminations	9/9
Support	**Adaptable** According to user's priorities Minimum 10% per criterion	By default 55% availability of relevant advice, 45% Affiliation to of a farm support network	6/6
Social durability of the system	**Adaptable** According to user's priorities Minimum 15% per criterion	Equal by default (workers' health risk due to pesticides, operational difficulties, adaptability)	6/80
Adaptability	**Fixed** by the designers With specialization disfavouring adaptability	20% specialization 80% farmer and employees' knowledge and skills	4/9
Operational difficulties	**Adaptable** According to user's priorities Minimum 20% per criterion	Equal by default (complexity and work hardness)	4/16

Work hardness	**Fixed** by the designers	50% physical difficulty and disturbance 50% work intensity	5/12
Complexity	**Fixed** by the designers	33% number of crops 33% risk of simultaneous operations 33% farmer and employees' knowledge and skills	10/18
Interaction with society	**Adaptable** According to user's priorities Minimum 10% contribution to employment and accessibility	By default, 35% contribution to employment and social accessibility, 15% societal value of landscape and acceptance	2/72
ENVIRONMENTAL SUSTAINABILITY	**Adaptable** Minimum 20 % for each criterion	Equal by default.	12/125
Resource use	**Adaptable** According to the context Minimum 25 % for energy Weight of mineral fertilizers equal or smaller than other. Avoid compensations between criteria: High or very high when one of the criteria (except mineral fertilisers) is very high. Should be adapted to the context	By default, 30% to energy use, land use and water use, and 10% to Mineral fertilizers use	46/256
Energy use	**Fixed** by the designers	60% energy consumption 40% energy efficiency	8/16
Energy consumption	**Fixed** Based on Pervanchon et al. 2002, Bonny, 1993	45% direct energy 55% indirect energy	7/16
Direct energy	**Fixed** Maximum between irrigation and machinery use	50% machinery use 50% irrigation	16/16
Machinery use	**Fixed** Based on Clements et al. 1995	15% deep tillage 30% superficial tillage 30% total number of treatment operations 25% fuel consumption at harvest	108/108
Indirect energy	**Fixed** Based on Pervanchon et al. 2002, Bonny, 1993	90% fertilizer manufacturing 10% pesticide manufacturing	8/20
Fertilizer manufacturing	**Fixed** Based on Bonny, 1993	80% N fertilizers 10% P and K fertilizers	32/64
Energy efficiency	**Fixed** by the designers	60% energy consumption 40% yield	20/20
Water use	**Adaptable** According to the context Higher weight for irrigation No impact of the risk when other criteria are favourable,	By default, 55% for irrigation, 15% for risk linked to dry periods and 30% for local availability of water	6/48

	No impact of the context when no irrigation		
Land use	**Fixed** by the designers	55% availability of uncropped lands 45% land intensity	4/16
Mineral fertilizer use	**Fixed** Based on systems described in the French ADAR project "Systèmes de culture innovants"	50% Mineral P fertilizer applications 50% Mineral K fertilizer applications	5/16
Environmental quality	**Adaptable** According to the context and to user's priorities Minimum 20% for each criterion	Equal by default (air, water, soil)	5/64
Water quality	**Adaptable** According to the context and to user's priorities Minimum 20% ground water, 10% for other	Equal by default (ecotoxicity, ground water and eutrophication)	6/64
Eutrophication potential	**Adaptable** According to the context	By default, 50% NO_3 leaching, 50% Phosphorus	5/16
Phosphorus	**Fixed** by the designers low when erosion risk is low	75% erosion risk 25% P surplus	4/16
NO_3 leaching	**Fixed** by the designers	40% leaching risk 35% capacity of crop sequence to uptake N 25% N surplus	13/32
Ground water quality	**Fixed** by the designers Maximum between pesticides and NO_3 leaching	Leading to 50% for each criterion (pesticides and NO3 leaching)	17/20
Pesticide leaching	**Fixed** by the designers Amount of pesticides null or Pesticide mobility null (no pesticides): pesticide leaching very low Amount low: pesticide leaching low or very low	35% total pesticide TFI 43% mobility 22% leaching risk	48/80
Aquatic ecotoxicity	**Fixed** by the designers low when the runoff risk is low	45% runoff risk 35% pesticide profile 20% heavy metals contamination	9/60
Pesticide profile risk	**Fixed** by the designers. Very low risk when the amount of pesticides or eco-toxicity is null Low risk when the amount of pesticides is null	41% Total pesticides TFI 59% toxicity	14/20
Soil quality	**Adaptable** According to the context and to user's priorities	By default, 50% physical, 25% chemical, 25% biological	11/64

	Physical higher or equal to others		
Physical quality	**Adaptable** According to the context Minimum 20% for compaction, erosion risk can be null	Equal by default (compaction and erosion risk)	5/16
Compaction risk	**Fixed** by the designers	50% proportion of autumn-harvest crops 50% Quantity of rain during harvest	5/16
Erosion risk	**Fixed** by the designers Worst between runoff and field erosion	Leading to 50% for each criterion	16/16
Field erosion risk	**Fixed** by the designers Frequent superficial tillage increases field erosion risk when it is low or very low	27% deep tillage, soil cover and context 19% superficial tillage	108/108
Runoff risk	**Fixed** by the designers Frequent superficial tillage decreases runoff risk when it is high or very high	27% tillage, soil cover and context 19% superficial tillage	108/108
Superficial tillage	**Fixed** by the designers (quantitative estimation)	30% superficial tillage in the crop 70% superficial tillage between crop	9/9
Chemical quality	**Adaptable** According to the context Minimum 25% per criterion	By default, 60% organic matter, 40% P fertility.	2/12
Organic matter	**Fixed** by the designers	45% organic amendment 30% deep tillage 25% stubble/straw management	15/32
Biological quality	**Fixed** Based on Bohanec et al. 2008	45% physical stress 35% chemical disturbance 20% fertilization intensity	10/60
Chemical disturbance	**Fixed** by the designers	70% Total Pesticide TFI 30% soil cover	6/15
Soil fertilisation intensity	**Fixed** by the designers	33% mineral N fertilizer applications 33% mineral P fertilizer applications 33% mineral K fertilizer applications	16/64
Air emission	**Fixed** by the designers	50% green house gases 30% NH_3 20% pesticide volatilisation	5/80
Greenhouse gases	**Fixed**	60% N_2O	9/16

	Based on Nemecek et al. 2008	40% CO_2	
N$_2$O emissions	**Fixed** by the designers, based on Bockstaller and Girardin, 2008	60% hydromorphic soil 40% N fertilizers	7/8
CO$_2$ emissions	**Fixed** Based on the energy consumption criterion	45% direct 55% indirect	7/16
N fertilizers	**Fixed** by the designers Maximum between organic and mineral fertilizers	Leading to 50% for each criterion	11/16
Pesticide volatilisation	**Fixed** by the designers	60% Total Pesticide TFI 40% Risk of pesticide drift due to material	6/15
Aerial and above soil biodiversity	**Adaptable** According to the context and to user's priorities Minimum 30% for each criterion	Equal by default (fauna and flora)	5/16
Fauna	**Adaptable** According to the context and to user's priorities Minimum 20% per criterion	Equal by default (pollinators, soil and flying natural enemies)	6/64
Soil natural enemies	**Adaptable** According to the context Minimum 20% deep tillage and habitat, 5% chemical pressure	By default, 50% deep tillage, 35% habitat network, 15% chemical pressure	7/64
Habitat network	**Fixed** by the designers	70% non-productive areas 30% habitat management	13/16
Flying natural enemies	**Adaptable** According to the context Less impact of pesticides in more complex landscapes Minimum 35% per criterion	By default 50% chemical pressure and flora	6/16
Pollinators	**Adaptable** According to the context Less impact of pesticides in more complex landscapes Minimum 25% per criterion, 20% crop effect (fixed).	By default 40% chemical pressure and flora, 20% crop effect	7/64
Chemical pressure on fauna	**Fixed** by the designers	70% TFI insecticides 30% TFI fungicides	8/16
Flora	**Adaptable** According to the context and to user's priorities Minimum 30% per criterion	Equal by default (natural/semi natural flora and weeds)	4/16
Natural/semi natural flora	**Fixed** by the designers	60% margin flora quality 40% chemical pressure	2/16
Margin flora quality	**Fixed**	60% habitat network	4/16

	by the designers	40% habitat management quality	
Weeds	**Fixed**	50% weed diversity	6/16
	by the designers	50% weed abundance	
Weed diversity	**Fixed** by the designers	50% crop types 20% intensification context 20% chemical pressure 10% margin flora quality	18/128
Weed abundance	**Fixed** by the designers	30% chemical pressure 20% crop type 20% superficial tillage between crops 15% superficial tillage in the crop (mechanical weeding) 15% inversion tillage	11/288

Appendix C: help and advice for estimation of some criteria

Sheet 1: Estimation of the criterion leaching risk

Effect of soil type and depth, climate, etc. on the risk of leaching. This may be estimated by the drainage indicator (rain during drainage period/total soil water holding capacity, CORPEN, 2006)

ID = Rain (Fall-Winter) / total soil water holding capacity

Examples of ID values

	Dry Winter (Rain = 200 mm)	Wet Winter (Rain = 600 mm)
Low soil water stock (50mm)	ID = 4 Medium	ID = 12 High
High soil water stock (150mm)	ID = 1.3 Low	ID = 4 Medium

Total soil water holding capacity (mm), depending on the soil texture, the rooting depth and the soil stone content (Comifer, 2002)

	Rooting depth of the following crop								
	Low: 35 cm			**Medium: 70 cm**			**High: 100 cm**		
	Volume load in stones (%)			**Volume load in stones (%)**			**Volume load in stones (%)**		
Texture	**0**	**0-20**	**>20**	**0**	**0-20**	**>20**	**0**	**0-20**	**>20**
Sand	50	40	30	100	80	60	140	120	80
Loam	100	90	60	200	180	120	300	240	180
Clay	120	100	60	240	200	140	340	300	200

Estimation of rooting depth (Bockstaller and Girardin, 2008)

Class for soil depth	Soil depth	Rooting depth
Superficial	< 60 cm	30
Medium	60 -90 cm	60
Deep	90-120 cm	90
Very deep	> 120 cm	120
Drained soil*		45

In case of drained soil, the water table depth is decreased during the drainage phase, so that the leaching risk is increased.

Estimation of soil water stock depending on soil depth and on texture

Soil depth	Texture					
	Sand	Sand-clay	Loam	Clay-sand	Clay-loam	Clay
Superficial	25	40	45	50	50	55
Medium	50	80	90	95	100	105
Deep	75	120	135	145	150	155
Very deep	100	160	180	190	200	205
Drained	75	120	135	145	150	155

 Sheet 2: Estimation of the criterion sowing density

Assessment of the sowing density for all crops of the crop sequence. Estimation of density (high, medium or low) highly depends on the region of assessment: soil type and climate (frost risk) leading to seedling death. The density is often higher in clay soils than in sandy soil (intermediate in loamy soils). Sowing density should be in accordance with sowing date: higher density when early or late sowing, because of higher seedling death risk.

Order of magnitude of sowing density per crops

Crop	Sowing density
Wheat	180-450 pl/m²
Maize	5-12 pl/m²,[a]
Winter barley	100-450 pl/m²
Spring barley	250-450 pl/m²
Sunflower	6-10 pl/m²
Winter oil seed rape	30-80 pl/m²
Pea	60-110 pl/m²
Sugarbeet	10-15 pl/m²
Potatoes	2-6 pl/m²
Flax	2100-2300 pl/m²

[a]8.5 to 10 for really early hybrids cultivars, 5 to 7 for the latest. The density is higher for silage maize, and can be higher if irrigation.

Sheet 3: Estimation of the criterion soil cover

Typical crop cover, average on the crop sequence, taking into account all crops in the crop sequence (*e.g.* values in the table below), as well as intercrop periods (bare soil, volunteers or intermediate catch crop)

Average soil cover depending on the period and on the crop (Bockstaller, 2007)

Crop	Winter period	Thunder period (Spring-Summer)	After harvest	Global over the cultural cycle[a]
Straw cereals	0-20 %	61-100%	61-100%	70-80%
Winter oilseed rape	21-61 %	61-100%	61-100%	80-90%
Pea	0	61-100%	61-100%	60-70%
Grain maize	0	21-60 %	61-100%	50-60%
Feed maize	0	0-20 %	0-20 %	30-40%
Sunflower	0	0-20 %	21-61 %	40-50%
Sugarbeet	0	21-61 %	0-20 %	40-50%

[a]for the estimation at the cropping system scale, these values should be completed with intercrop periods

Sheet 4a: Estimation of the criteria pesticide mobility and pesticide eco-toxicity in maize cropping systems

Estimation of pesticide active ingredient[8] mobility using the Ground water Ubiquity Score (GUS)[9]

Scale[a]	Pesticide active ingredients[b]	GUS
High	dicamba	3,80
	nicosulfuron	3,64
	imidaclopride	3,59
	fluroxypyr	3,37
	bentazone	3,03
	2,4-MCPA	2,98
	S-métolachlore	2,93
Medium	terbuthylazine	2,57
	2,4 D esters	2,32
	isoxaflutole	2,21
	flutriafol	2,17
	chlorothalonil	2,09
	acétochlore	2,08
	mésotrione	1,90
	azoxystrobine	1,85
Low	bromoxynil phenol	1,76
	flusilazole	1,54
	glyphosate	1,51
	bromoxynil octanoate	1,24
	chlorpyriphos-éthyl	0,62
	chlorpyriphos-méthyl	0,44
	cyperméthrine	-1,48
	lambda-cyhalothrine	-1,71
	deltaméthrine	-2,50
	alphaméthrine	-0,31
No pesticide	n/a	

[a] High: >2.8, Medium: 1.8-2.8, Low: <1.8 (van der Werf & Zimmer, 1998; INDIGO, 2007)
[b] Herbicides Insecticides Fungicides

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[8] Active ingredient in commercial products can be found on http://e-phy.agriculture.gouv.fr/
[9] Koc and DT 50 values for estimation of GUS were obtained mainly from Agritox database (INRA) and partially from the Pesticide Manual (UK), ARS database (USA) and RIVM (Netherlands)

Estimation of pesticide active ingredient eco-toxicity using Aquatox and Rate of application[10]

Scale[a]	Pesticide active ingredients[b]	Aquatox	Rate of application[c]	Pesticide eco-toxicity[d]
High	chlorpyriphos-éthyl	0,000176	High	**High**
	lambda-cyhalothrine	0,00021	High to medium	**High**
	alphaméthrine	0,0003	Medium to low	**Medium**
	cyperméthrine	0,0003	Low	**Medium**
	chlorpyriphos-méthyl	0,00108		
	acétochlore	0,0013		
	deltaméthrine	0,0039		
	S-métolachlore	0,008		
Medium	terbuthylazine	0,016	High	**High**
	bromoxynil octanoate	0,06	High to medium	**Medium**
	bromoxynil phenol	0,063	Medium to low	**Medium**
	chlorothalonil	0,07	Low	**Low**
	2,4 D esters	0,19		
	azoxystrobine	0,2		
	isoxaflutole	0,33		
	flusilazole	1,2		
	mésotrione	4,5		
	bentazone	10		
	imidaclopride	10		
	flutriafol	12		
	glyphosate	15		
	2,4-MCPA	50		
	fluroxypyr	50		
	nicosulfuron	65,7		
Low	dicamba	107	High	**Medium**
			High to medium	**Medium**
			Medium to low	**Low**
			Low	**Low**
No pesticide	n/a		n/a	

[a] High: <0.01, Medium: 0.01-100, Low: >100 (van der Werf & Zimmer, 1998; INDIGO, 2007)
[b] Herbicides Insecticides Fungicides
[c] High: >10 kg ha^{-1}, high to medium: 10-5 kg ha^{-1}, medium to low: 5-0.01 kg ha^{-1}, low: <0.01 kg ha^{-1} (van der Werf & Zimmer, 1998; INDIGO, 2007).
[d] Pesticide eco-toxicity derives from combining the Aquatox result for active ingredients (high, medium, low) with the rate of application scale (high, high to medium, medium to low, low). Example: S-metolachlor with high Aquatox if the applied rate is high then eco-toxicity is high.

[10] Aquatic toxicity is based on biological effects on three aquatic species forming a food chain: algae (EC50), crustaceans (EC50) and fish (LC50). Values were obtained by Agritox database of INRA

endure
diversifying crop protection

Sheet 4b: Estimation of the criteria pesticide mobility and pesticide eco-toxicity in winter crop cropping systems

Estimation of pesticide active ingredient[11] mobility using the Ground water Ubiquity Score (GUS)[12]

Scale[a]	Pesticide active ingredients[b]	GUS
high	mesosulfuron-methyl	4.48
	iodosulfuron-méthyl-sodium	4.40
	thifensulfuron-méthyle	3.62
	metsulfuron méthyle	3.55
	lénacile	3.54
	krésoxim-méthyl	3.49
	fluroxypyr	3.37
	carfentrazone-éthyle	3.02
	2.4-MCPA	2.98
medium	quinmérac	2.63
	flupyrsulfuron-méthyl	2.62
	isoproturon	2.56
	métamitrone	2.55
	2.4-DB sel dimethylamine	2.54
	clopyralid	2.51
	diméthachlore	2.47
	éthofumesate	2.38
	diniconazole	2.30
	clomazone	2.25
	napropamide	2.25
	pyrimicarbe	2.15
	propaquizafop	1.91
	époxiconazole	1.90
	propyzamide	1.90
low	bromoxynil phenol	1.76
	métazachlore	1.65
	flusilazole	1.54
	diflufenicanil	1.53
	glyphosate	1.51
	ioxynil	1.34
	bromoxynil octanoate	1.24
	fenpropidine	1.21
	2.4-DB esters	1.17
	prochloraze	1.12
	cyprodinil	1.06

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[11] Active ingredient in commercial products can be found on http://e-phy.agriculture.gouv.fr/

[12] Koc and DT 50 values for estimation of GUS were obtained mainly from Agritox database (INRA) and partially from the Pesticide Manual (UK), ARS database (USA) and RIVM (Netherlands)

malathion		0.71
aclonifen		0.55
bifénox		0.38
pyraclostrobine		0.29
cyperméthrine		-1.48
lambda-cyhalothrine		-1.71
tau-fluvalinate		-3.20
No pesticide	n/a	

[a] High: >2.8, Medium: 1.8-2.8, Low: <1.8 (van der Werf & Zimmer, 1998; INDIGO, 2007)
[b] Herbicides | Insecticides | Fungicides

Estimation of pesticide active ingredient eco-toxicity using Aquatox and Rate of application*

Scale[a]	Pesticide active ingredients[b]	Aquatox	Rate of application[c]	Pesticide eco-toxicity[d]
high	lambda-cyhalothrine	0,00021	high	**High**
	cyperméthrine	0,0003		
	tau-fluvalinate	0,0009	high to medium	**High**
	malathion	0,0010		
	diflufenicanil	0,0024	medium to low	**medium**
	flupyrsulfuron-méthyl	0,0037	low	**medium**
	fenpropidine	0,0057		
	aclonifen	0,0067		
	isoproturon	0,0100		
medium	carfentrazone-éthyle	0,0120		
	lénacile	0,0150		
	thifensulfuron-méthyle	0,0159		
	krésoxim-méthyl	0,024		
	métazachlore	0,032		
	metsulfuron méthyle	0,045		
	diméthachlore	0,053		
	bromoxynil octanoate	0,060		
	pyraclostrobine	0,060		
	bromoxynil phenol	0,063		
	iodosulfuron-méthyl-sodium	0,07		
	pyrimicarbe	0,08		
	prochloraze	0,10	high	**high**

	propaquizafop	0,19	high to medium	**medium**
	mesosulfuron-methyl	0,20	medium to low	**medium**
	métamitrone	0,22	low	**low**
	2,4-DB esters	0,40		
	2,4-DB sel dimethylamine	0,40		
	bifénox	0,47		
	époxiconazole	0,50		
	cyprodinil	0,67		
	propyzamide	0,83		
	flusilazole	1,20		
	diniconazole	1,58		
	clomazone	2,90		
	ioxynil	3,14		
	éthofumesate	3,9		
	clopyralid	6,9		
	napropamide	12,2		
	glyphosate	15,0		
	quinmérac	48,5		
	2,4-MCPA	50		
	fluroxypyr	50		
Low			High High to medium Medium to low Low	**Medium** **Medium** **Low** **Low**
No pesticide	n/a		n/a	

[a] High: <0.01, Medium: 0.01-100, Low: >100 (van der Werf & Zimmer, 1998; INDIGO, 2007)

[b] Herbicides Insecticides Fungicides

[c] High: >10 kg ha^{-1}, high to medium: 10-5 kg ha^{-1}, medium to low: 5-0.01 kg ha^{-1}, low: <0.01 kg ha^{-1} (van der Werf & Zimmer, 1998; INDIGO, 2007).

[d] Pesticide eco-toxicity derives from combining the Aquatox result for active ingredients (high, medium, low) with the rate of application scale (high, high to medium, medium to low, low). Example: S-metolachlor with high Aquatox if the applied rate is high then eco-toxicity is high.

 Sheet 5: Estimation of the criterion Coverage of crop Nitrogen requirement

Should take into account the amount of N fertilizers, the requirement of the crop and the yield. A deficiency could be tolerated for some reasons, or occur because of a miscalculation of the doses supplied, whereas a surplus could occur for example in a situation where high protein content is required.

Nitrogen needs of some crops (source: Azobil, Taureau et al. 1996)

Nitrogen needs (kg/ha) for crops harvested in vegetative stage	
Sugar beet	220
Potatoes	220
Chicory	110
Carrots	150
Spinach	250
Onions	160
Nitrogen needs (kg/q) for crops harvested as grain	
Winter wheat	3
Winter barley	2.2
Rye	2.3
Spring wheat	2.2
Durum wheat	3.5
Oat	2.2
Oilseed rape	6.5
Maize (grains)	2.2
Maize (fodder)	14 kg/t DM
Flax (fibbers)	10 kg/t DM
Flax (grains)	5
Sunflower	4.5

Sheet 6: Estimation of the criterion capacity of crop succession to uptake N during leaching periods

The capacity of crop succession to uptake N should be estimated at the cropping system level based on the crop risk of NO_3 leaching that is estimated between 2 successive crops.

Crop risk of NO3 leaching depending on the couple preceding/following crop (Comifer, 2002)

Duration without N uptake	Stubble: biomass and %N	N uptake capacity before the beginning of drainage	Organic N supply in Fall	Crop risk of NO_3 leaching
N uptake can stop before the harvest of the previous crop (e.g. potatoes) and start after the sowing of the next crop (e.g. winter cereals)	Determines the possibility of N mobilization during stubble degradation	Determines the amount of N available for leaching	Increases the risk of N leaching	Results from the four components
Very short Short Long Very long	- High amount and low %N (cereal, maize, sunflower straws) - Medium amount and low %N - Low amount and low %N (cereal stubble) - Low amount and high %N (potatoes, vegetables, sugarbeet) - Medium amount and high %N (peas, soya beans) - High amount and %N (rape, alfalfa, pastures)	High (WOSR, catch crop) Low (winter cereals) Null (bare soil)	No Yes, C/N>8 Yes, C/N<8	Very low Low Medium High Very high

Example of estimation of the crop risk of NO3 leaching for some couples preceding/following crop (Comifer, 2002)

Couples of preceding and following crops	Duration without N uptake	Stubble of the preceding crop		N uptake capacity before the beginning of drainage	Crop risk of NO_3 leaching
		Biomass	**%N**		
Beetroots-wheat	Very short	+	+++	Low	Low
Maize-wheat	Very short	+++	+	Low	Medium
Wheat (exported straws)-rape	Short	+	+	Medium to high (depends on date of sowing and emergence of rape)	Very low to low
Wheat (buried straws)-rape	Short	+++	+	Medium to high (depends on date of sowing and emergence of rape)	Very low to low
Sunflower-wheat	Short	++	+	Low	Medium
Rape (without volunteers)-wheat	Long	+++	++	Low	Medium to high
Pea-wheat	Long	++	++	Low	Medium to high
Wheat (buried stubble)-wheat	Long	+++	+	Low	Medium
Potato-wheat	Long	+	++	Low	High
Spinach-wheat	Long	++	+++	Low	Very high
Wheat (buried stubble)-spring crop (maize, pea, sunflower)	Very long	+++	+	Null	Very high
Beans-maize	Very long	++	++	Null	Very high
Grain maize-maize	Very long	+++	+	Null	High

N amount released from stubble (Comifer, 2002; Bockstaller and Girardin, 2008)

Crops	Stubble management	N amount released (kgN / ha)
Sugarbeet	Buried leaves before 1/10	+20
	Buried leaves after 1/10	+10
	Exported	0
Straw cereals	Buried straws	-20
	Exported, mulch	0
	Burnt	+40
	Volunteers	-20
Rape	Buried stubble	+10
	Volunteers	-25
Fallow	Buried before 1/09	+50
	Buried after 1/09	+30
Alfalfa	Buried before 1/09	+50
	Buried after 1/09	+30
Maize	Buried before 1/10	-10
	Buried after 1/10, mulch	0
Peas	Buried	+20
	Mulch	0
Potatoes and vegetables	Buried leaves before 1/09	+50
	Buried leaves after 1/09	+30
	Buried leaves after 1/10	+10
Meadow	Buried before 1/09	+200
	Buried after 1/09	+150
	Buried after 1/10	+100
Soya bean	Buried before 1/09	+50
	Buried after 1/09	+30
	Buried after 1/10	0
	exported	0
Sunflower	Buried before 1/10	-10
	Buried after 1/10	0