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COLLABORATIVE PROJECT

AMIGA

Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

WP3 Long term effects

Deliverable 3.5 Report on Limits of concern - summary

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PU	Public	
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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	**X**

Preamble

The topic *Limits of Concern* permeates many aspects of work in AMIGA. Therefore to integrate various interests, a workshop on *Limits* was held in Dundee, UK in June 2014 and a Task Force set up within AMIGA to ensure the various analyses and activities were coordinated.

Deliverable 3.5 in WP3 on *Long term effects* is part of this broad effort on *Limits*. Deliverable 3.5 attempts to define actual ecological limits through analysis of field-scale experimental data. Some of this data was generated in past field experiments on GM cropping. Much other data was collated from field experiments and surveys that did not include GM crops but which allowed some definition of limits for factors such as soil biophysical condition and seedbank.

The outputs for this deliverable consist of a formal report and several papers for refereed journals. By way of synthesis, limits for all variables are being incorporated in a Multi-Attribute Decision Model (MADM) covering receiving environments and GM impacts and which will be released with the final report of WP3.

Since collaborations with other parts of the *Limits* Task Force and the construction of the MADM are still in progress, the present document is intended as an interim summary of the work and gives a brief description of the MADM.

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Summary - Limits of concern and safe ecological ranges

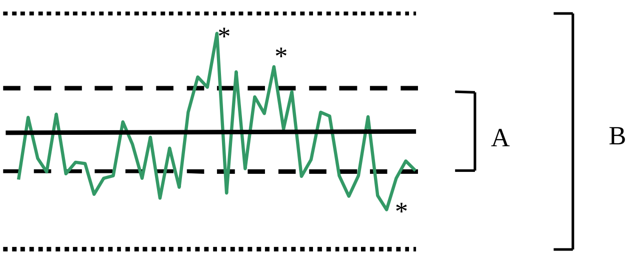
- **Scope**. The idea of 'Limits of Concern' has become important in risk assessment. It is based on the fact that many ecological entities, such as populations and processes, vary through time and differ between locations, but may do so within limits or ranges in which the population or process is not permanently affected. On the other hand, the variation might take the population of process into unsafe territory and eventually to degradation and destruction.
- **Definitions**. In this report, 'safe ecological ranges' is used rather than 'limits of concern'. In risk assessment, the latter tends to be expressed as an arbitrary range (e.g. a factor of two) because the actual, biological, limits are not known. The expression 'safe ecological ranges' here signifies that experimental data are examined in order to define the transition point at which a population or process passes from an ecologically safe state to one where is performs sub-optimally or starts to degrade.
- **Framework and approach**. The approach considers processes in relation to upper and lower limits: an outer pair of limits within which the process operates and an inner pair within which it operates optimally or without restraint. These limits are defined in Box 1. A crucial aspect of this work is that a population or process must be linked to an ecological function: the limits in the population or process are defined by what happens to the function.
- **Sources of experimental data**. The data used in attempts to define the limits in Box 1 were from the following main sources: a) GMHT crop trials carried out in the UK in the period 1999-2005, b) synthesis in the EU SIGMEA project from field experiments on GM impacts and geneflow, mainly over the period 2000-2007, and c) more recent on-farm surveys and field experiments at a range of locations in Europe (2007-2014).
- **Variables examined**. The analysis concentrates on a set of processes and functions, primarily: a) crop production and yield; b) the seedbank as a source of weed mass and species composition; c) the weed flora as support for the food web and as a limitation to yield; d) nitrogen as a driving component of plant mass and as a pollutant. An example of a safe ecological range was defined in the arable

seedbank (b above): a value of around 2000 m^{-2} (seeds per square metre of field) is generally enough to support a diverse weed flora; values lower than this limit the emerged flora, while values much greater will add little to the flora and may generate a serious weed problem.

- **Common currencies**. Where a single variable affects two major functions (as does weed mass, for example, in supporting the food web and competing with the crop) the variable should ideally be expressed in a currency that is widely understood, so that potential trade-offs between the functions can be evaluated. Among the more useful currencies is nitrogen content (kg ha^{-1}) which is a driving constituent of weed mass and a nutrient and cost understood by farming and policy.
- **Conclusion**. Considerable experimental resources are needed to estimate safe ecological limits for the entities listed above. While substantive progress has been made in nitrogen partition, soil carbon, weeds and food webs, the information required to estimate limits for many other indicators is not generally available or may not be available for a specified receiving environment and cropping system. In many of these cases, however, the range of effect (from high risk to low risk) and direction in which an indicator should move, may be known. In practice therefore, risk assessment is being progressed using a combination of actual (measured, estimated) and subjective (expert opinion) limits of concern.
- **Multi-attribute decision tree.** The receiving environments in which GM crops might be tested or grown are being represented by a multi-attribute decision tree based in DEXi software. The tree links agronomic interventions through life forms and ecological processes to ecosystem services. Annex A summarises the structure and working of the tree. Each set of input variables or derived attributes in the tree is defined in terms of ranges and limits which signify the degree to which life forms or processes are at risk.

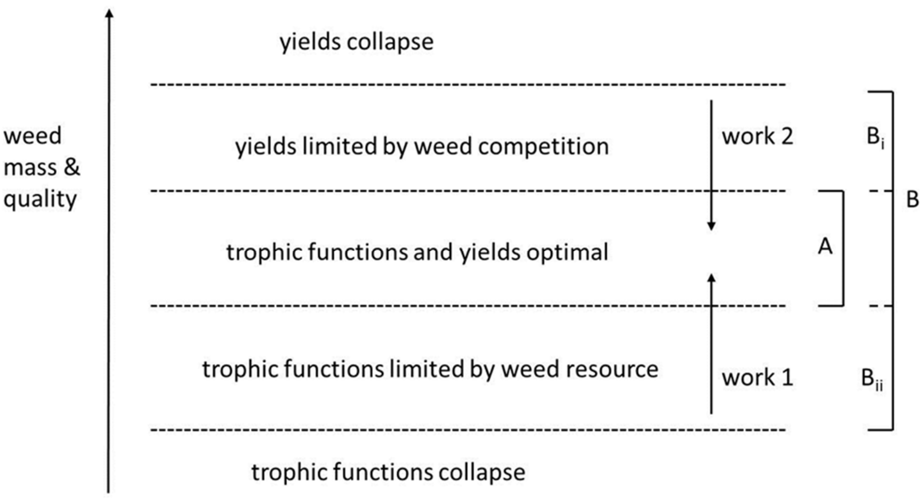
Box 1. Safe limits

The concept of 'safe ecological limits' is being used to define a sustainable comparator in studies of the potential long-term effects of agricultural change. Three states need to be compared: the current system, this system with the proposed change, such as a GM crop, and a system in a 'safe' or sustainable state. The safe system may be hypothetical, for example if agricultural intensification has already driven populations and processes into unsafe ranges.



The diagram to the left shows a population or ecological process varying through time. Within range A, it will continue to operate indefinitely and sustainably. Outside A but within B it will operate less effectively.

Work can be applied at * to bring the process back within A. However, if the process moves outside B, it will collapse. Examples of collapse include a soil that has lost most of its organic carbon, lacks cohesion and is eroded away; and a soil-microbe-plant system poisoned by long term exposure to heavy metals.



The upper and lower limits of A and B can refer to the same function. For example, the pore space in soil for fine roots and fungal hyphae may be limited by low soil strength due to lack of structure and high soil strength due to impenetrability.

However, the upper and lower limits may refer to different functions that can be combined in one diagram. In the example above, the vertical axis represents the mass and quality of the weed flora cohabiting with crops. The lower limit refers to the support that the flora gives to the farmland food web; the upper limit refers to the competitive effect of weeds on the crop. Here, range A signifies an optimum state where both functions are satisfied. In ranges Bi and Bii, work of different sort is needed to return the system to an optimal state.

After Squire, GR (in preparation)

Annex A. Multi-attribute decision model linking interventions to ecosystem services

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The widely used DEXi decision tree software has been adapted to form a multi-attribute decision model for assessing receiving environments and GM impacts. The model is based on the chain interventions/innovations – life forms – ecological processes – ecosystem services that forms the basis of all tasks in WP3.

The model operates by combining the effects of input attributes (e.g. agronomy, populations) into aggregated attributes (e.g. soil carbon status, omnivore status, cross pollination) which then combine into a higher-level process or service (root attribute in Fig. A1).

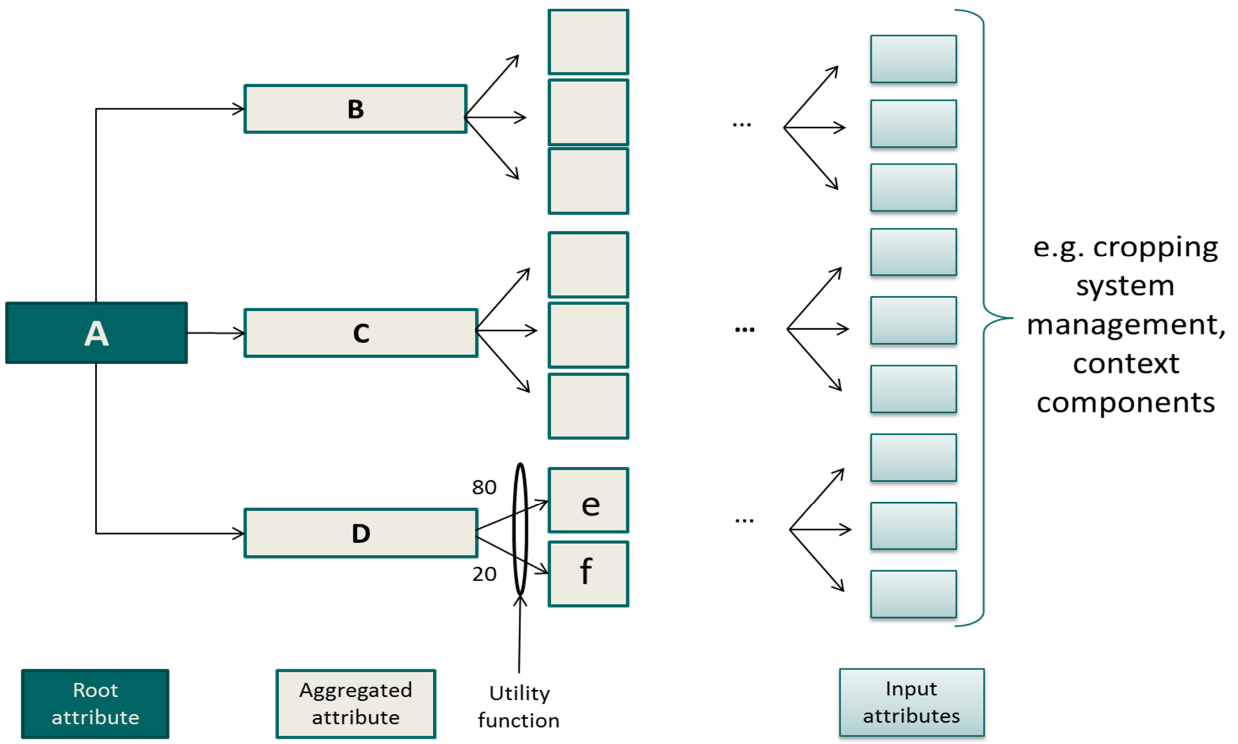

Fig. A1. Structure of a decision tree.

At each stage, the attributes (in the boxes in Fig. A1) are defined in terms of risk – very high to very low, that is, defining whether the attribute is in a safe ecological range or not or somewhere in between. In some instances, experimental information enables the 'boundaries' between risk categories to be quantified. In other instances, the boundaries are defined by expert judgement.

A decision tree has been constructed in AMIGA to cover provisioning, supporting and regulating services. For illustration, the part pertaining to provisioning is shown in Fig. A2. Yellow boxes signify input variables, blue boxes state variables (of the receiving environment) while orange boxes indicate a link to another part of the tree.

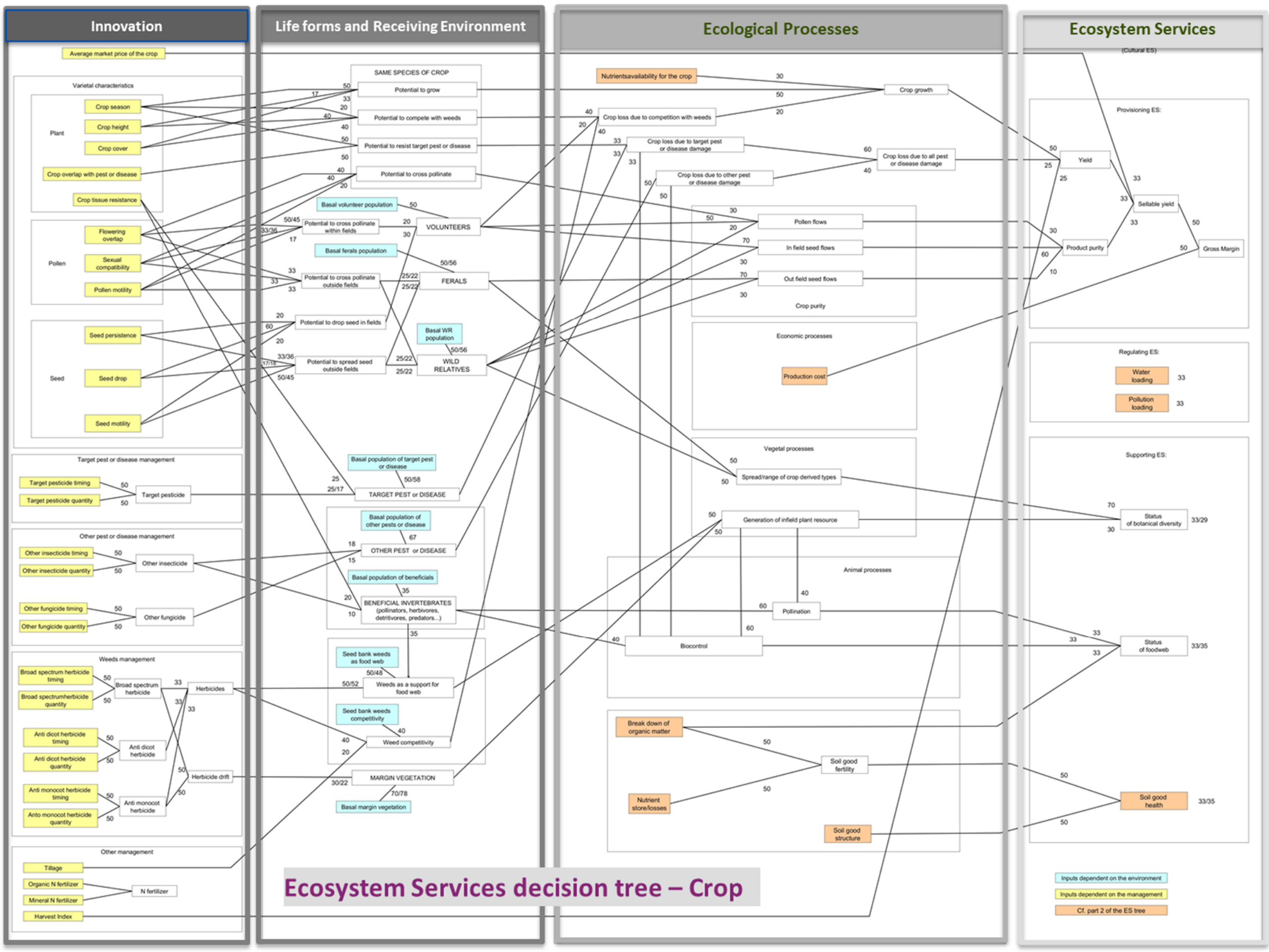

Fig. A2. Part of the multi-attribute decision model (MADM) linking interventions/innovations through life forms and ecological processes to ecosystem services. The complete model, at a resolution to show all linkages and structures, will be made available in the final report of WP3.

The programme is ‘worked’ on-line (Fig. A3). The functions linking the various attributes can be modified to show how the weightings allocated to different variables influence the outcome.

The MADM is being used to compare the 8 systems defined by crop and management in the Farm Scale Evaluations of GM herbicide tolerant crops (UK). These will set a multi-dimensional space against which most other GM cropping systems can be compared, including blight-tolerant potato and Bt maize.

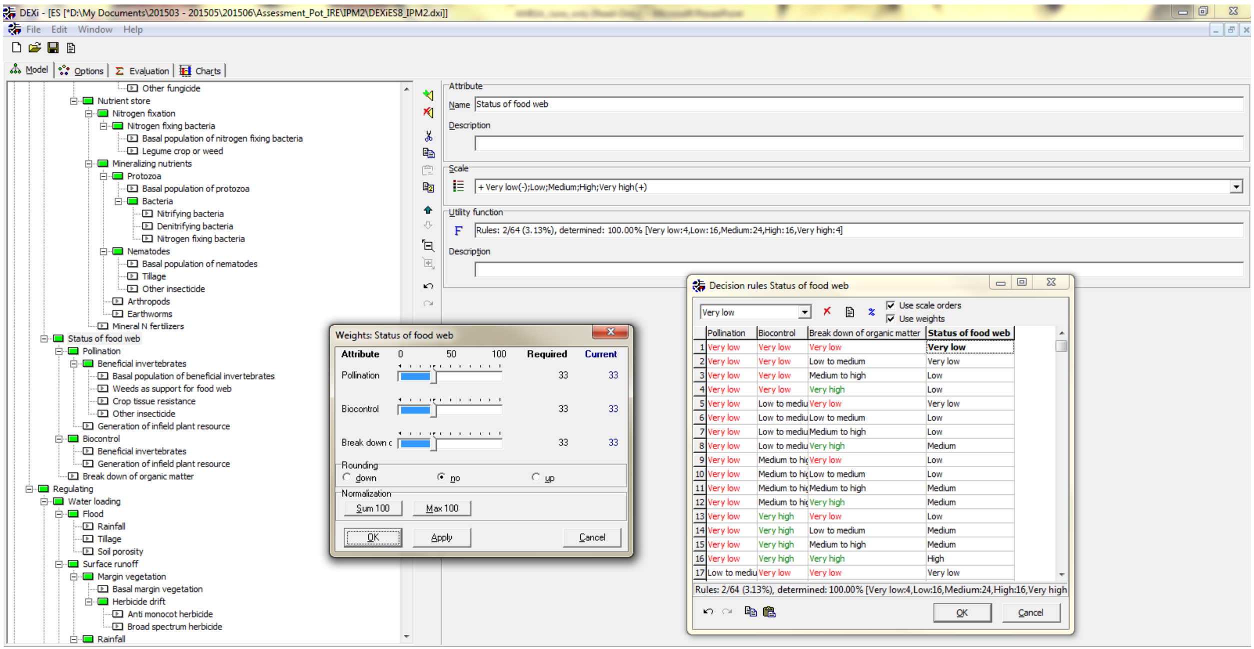

Fig. A3. Screen shot of the Dexi decision model. The left hand column shows part of the decision tree. The inset boxes define the utility functions that determine how branches of the tree are combined.