Agrotechnologies towards Ecotechnologies – the three pillars for developing Eco-design

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Summary:

To boost agrotechnologies towards ecotechnologies ("environmental technologies" according to ETAP programme of EU, or "more ecologically productive technologies" in the context of agriculture), we need to strengthen a "triple bottom" system:

- ✓ To take into account, in "Life Cycle Analysis" methodologies, the natural variability in time and space of these applications in land use.
- ✓ To develop an overall approach for realistic machinery qualification, in order to feed the environmental burdens accurately through relevant data bases collected on agrotechnologies in real action.
- ✓ To work on Eco-innovation processes, by deepening specific innovation tools and methods, for implementation of innovative solutions chosen according to LCA results.

This paper presents the concept, develops the methods and illustrates them by examples of results on organic spreading technologies.

Keywords: Eco-design - Machinery assessment – Life Cycle Analysis – Eco-innovation

Introduction

The concept of Environmental Technologies[1] really emerged in 2004 thanks to ETAP (Environmental Technologies Action Plan), a programme launched by the European Commission. In France, this concept has been transformed in "Ecotechnologies" (term more ambiguous) and a national programme has been led since 2005, called "Ecotechnologies and Sustainable Development", in which the project ECODEFI (Eco-design and development of eco-assessment and eco-innovation methodologies) is operational with now, some results that can be presented.

[1] *"Environmental technologies include both integrated technologies that prevent pollutants being generated during the production process, and end-of-pipe technologies that reduce the release into the environment of any pollutants. They can also include new materials, energy, and resource-efficient production processes" – extract from M. Galatola's presentation in European commission conference on "Towards European methodology for environmental technology assessment" – october 2006.*

A "system" approach for boosting agrotechnologies in ecotechnologies

Agricultural technologies have a big potential for being classified in "environmental technologies" because agricultural activity allows reducing environmental burdens of human activities by using organic wastes and sludge in biomass production. By this way, it's a traditional "pollution treatment" technology, but it can be also a "cleaner technology" as we are able to design new technologies which reduce pollutant flows at all stages of life cycle, especially during the use phase, dedicated to agricultural production. We are going to highlight some main research tracks enable to boost this "eco-design" concept[2].in this sector.

Without a multicriteria and quantitative assessment of environmental burdens on a clear application field, it's impossible to claim an objective environmental benefit. So, we promote a "top-down" approach which use, at first, "Life Cycle Analysis3 (LCA) methodologies in order to classify and measure the main impacts occurred by the classical technology that we want to improve. Thus, we are able to identify the good tracks for innovation researches. Moreover, to be relevant, this quantitative environmental assessment need to be fed by realistic and specific datas, provided by some practical measurements on machineries in work situation. It is the technology qualification. Besides, innovation process can be strengthened and more efficient by using specific creativity methodologies, supported by a strong knowledge of operational mechanisms.

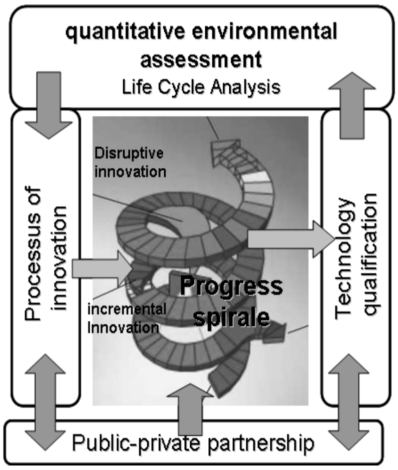

Figure 1: *A "system" approach for boosting Ecodesign process.*

However, the practice of this procedure on real situations has identified some scientific and technical bottlenecks in three research areas:

➢ Accounting for variability in the Life Cycle Assessment methodology.

Data collection is the most time consuming and costly part of LCA studies. This is especially true for agriculture as field emissions are highly variable, depending on climate, soil type and farming practice [Audsley and al., 2003]. Therefore, there is a challenge to rate a technology in a generic and accurate way when its performance depends on many inter-related factors.

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[2] The product eco-design aims to optimise environmental performances at the same time than keeping quality of use (*UE official newspaper of 15/02/05 – C38E/45*) – Eco-design is a preventive approach which takes into account environment as soon as the design work phase.

[3] **Life Cycle Assessment (LCA)** is since 1997 an internationally standardised method (ISO 14040) for the evaluation of the potential negative impacts of goods and services (products) along their life cycle on the environment, human health, and resource availability. LCA helps to avoid the "shifting of burdens" among life cycle phases, among the various impacts, and among countries – extract of " European Platform on Life Cycle Assessment" - LCA@JRC.it - http://lca.jrc.ec.europa.eu/

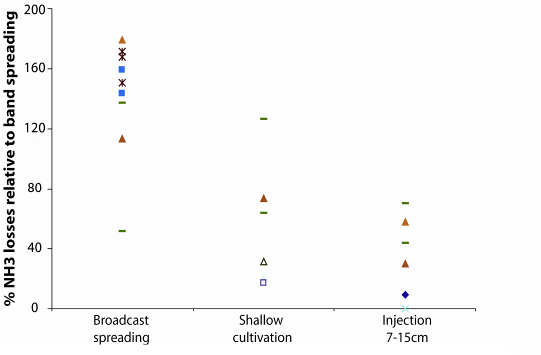

Figure 2: *Relative NH_3 losses factors for slurry application techniques*

The case of manure application techniques illustrates the complexity of such an assessment.

Fig. 2 shows NH_3 losses following slurry application with different techniques expressed as a percentage of NH_3 losses with the band spreading technique [Langevin and al., 2008]. It clearly shows the variability of the technique performance, even if rough trends can be outlined.

One possibility to overcome the challenge of rating such agrotechnologies would be to draw up the environmental profile of the studied technology, i.e. its performance in a number of contrasted situations.

In the case of manure application, agro-ecological modelling at the field scale could be used to quantify the polluting emissions in contrasted situations of soil, climate and practice, and these data could be further integrated into a complete LCA for all selected situations, constituting an environmental profile for the technology under study.

➢ Developing machinery qualification by an overall approach

Metering is a basic principle to enhance environmental performances of a machine. The development of sensors has largely contributed to the advances in precision agriculture enabling to correct the inputs according to agro-ecological needs. But the good achievement of the modulations would require a strict command of the machine to accurately execute its task.

To verify the functioning of the machines, it has been necessary to set up sophisticated test benches measuring technological performances under accurately controlled conditions. The European Network for Testing Agricultural Machines (ENTAM) connects most of the European test centres and actively participates to the sharing of experience and the sharing of test results. By this way ENTAM encourages the development of up to date installations.

Specific tools have been set up in order to bridge the gap between indoor benches metering conditions and field working conditions.

The "Spreading Simulator" [Piron et al, 2009] has been designed to assess the performances of a spreader in real-world geographic context. It is supplied by the results of the test benches obtained with standard procedures. It delivers a realistic application rate mapping which could not be acquired by any other available mean. Fig. 3 illustrates the simulation results and their analysis provided by the software.

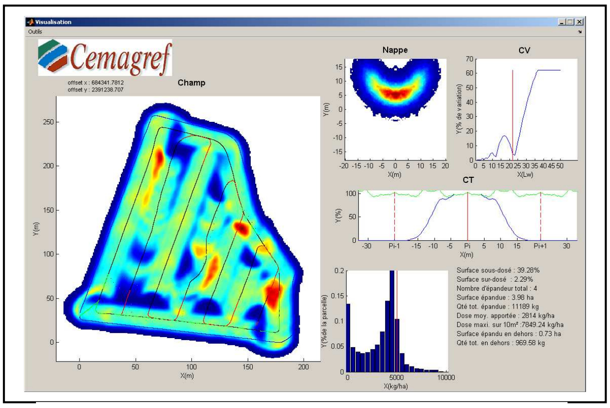

Figure3: Results window of a spreading simulation

A further step is needed to link the measured technological indicators with potential environmental impacts. Field emissions contribute to the total potential impacts; as they depend on practice and soil and climate conditions. It is then necessary to specify a set of reference conditions to assess these impacts.

Considering that the future working conditions of the machine are unknown at the time of its manufacturing, it is necessary to take into account the occurrence of sensitive environments and ignore ideal situations where, for example, the soil will absorb damages due to hazardous practices

The choice of the reference conditions will be guided by the results of the LCA sensitivity study, by the questioning of agronomical and environmental experts and also by the integration of good practice codes requirements. Once the reference conditions are stated, models may be used to quantify the emissions and the subsequent potential impacts accordingly.

➢ Working on Eco-innovation processes

The term "environmental innovation (eco-innovation)" has been introduced by the interdisciplinary project 'Innovation Impacts of Environmental Policy Instruments' (Klemmer et al., 1999). To eco-innovate, several leads are possible such as dematerialization, moving from products to services, durability and versatility.

In our case study of spreading technologies, we can take example of the increase of machine versatility, in order to spread properly not only mineral but also organic fertilizers specially the cohesive ones.

The major noted problem with this type of product is the flow rate decrease during the time of discharge. To identify the origin of this problem, we have recourse to the Root Cause Analysis by utilizing the cause-effect model (Figure 4). Because one event in the chain causes the next, solving any of the preceding events will solve the problem.

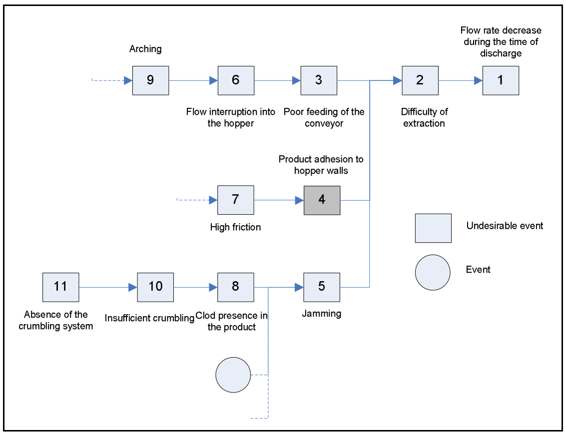

Figure 4. Cause-effect model -"flow rate decrease" can be occurred by "product adhesion to hopper walls", "jamming", …

Once the ''core'' problem is identified, we generate concepts by using the Theory of Inventive Problem Solving (TRIZ). TRIZ is a knowledge –based methodology, for accelerated development of design concepts. Also, it is a creative problem-solving methodology especially tailored to scientific and engineering problems.

To seek solutions to each category of problem, it is essential to scan several (or all) TRIZ tools and methods. The most important tools and methods of the TRIZ methodology are the Contradiction Matrix, the 40 Inventive Principles, the 39 TRIZ Parameters, the ARIZ Algorithm, the 76 Standard Solutions, the Su-Field analysis, the laws and trends of technology evolution, the System of Operators, the Effects and Anticipatory Failure Determination (Serban et al., 2004; Savransky, 2000).

As an illustrative explanation, the scientific effects tool is introduced. According to TRIZ, the scientific effect is one of the principles for resolving physical contradictions. There are about 10,000 effects described in the scientific literature (Kraev, 2007). Each effect may be a key to solving a large group of problems (Savransky, 2000).

For "product adhesion to hopper walls" problem, several effects have been found so that reduce sliding frictional force. Among these effects, we may mention: normal force increases friction between objects / vibration / surface roughness affects sliding friction / solid lubricant reduces friction coefficient / Adsorption and desorption affect adhesive force between solids.

Eventually, the designer chooses one or more effects that have the highest likelihood of efficiency in a defined situation. The choice of effect is contingent upon the industrial expertise and practice of the company.

In fact, to succeed in root cause analysis and to establish the "cause-effect" tree, a good understanding of occurred mechanisms is required. Especially, a deepened mastering in fluid mechanics is necessary for technological problems which concern matters (liquid, pasty or heterogeneous solid) with movement in interaction with devices and machines.

Conclusion:

So, in Eco-design, we need to have a "system" approach, associating environmental assessment (LCA), fed by realistic and global machinery qualification processes, in order to guide relevant innovations.

However, whatever the novel solution, even more so if it's a disruptive innovation, this one must be adaptable and compatible with end-user practices. So, this dimension must be taken into account in early stage. At the same way than for Eco-design concept, a participatory design concept can be adopted as soon as the beginning of the work, for targeting effective solutions.

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A special thanks to ANR (French Research National Agency) for having supported the ECODEFI project.