DEXiPM-Grapevine©: a multicriteria assessment tool of the sustainability for grapevine farming systems

DEXiPM-Vigne©: un outil d'évaluation multicritère de la durabilité des systèmes viticoles

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Abstract
The development of innovative farming systems to reach news goals of agricultural sustainability needs new methods for efficiency assessment. DEXiPM-Grapevine© is a multicriteria assessment tool for overall sustainability of grapevine farming systems adapted from DEXiPM arable crops (Pelzer *et al*, 2012). DEXiPM-Grapevine© was implemented during the European PURE Project 2012-2015 (Integrated Pest Management (IPM) solutions in agriculture) in order to assess and compare various innovative grapevine systems. This model includes 65 basic attributes describing the cropping system, which are then combined into 97 aggregated attributes, designed to assess the economic, social and environmental performances. This model is based on expert knowledge and agricultural surveys, to define thresholds of classes for each attribute and the weighting of the aggregations. A guide helps users to adjust these parameters specific features due to local context.
We tested DEXiPM-Grapevine© on innovative grapevine systems, designed with low pesticides use, and experimented at field scale in the French EcoViti Network. We made both ex ante and ex post analyses of experimented systems in order to sort them and to adjust their strategies. Three main strategies of pesticide reduction are explored: (i) IPM, (ii) alternative products, organic and biocontrol approach, (iii) pesticide-free cropping systems based on new grapevine mildew resistant varieties. Seven prototypes are tested on INRA experimental farms in Angers (Loire Valley (center of France), Bordeaux (Atlantic region), and Montpellier (mediterranean region)).
The first DEXiPM-Grapevine© assessments show a high environmental performance of innovative biocontrol strategies, and new resistant varieties. However, IPM strategies have the best overall sustainability with better economic and social assessments.
DEXiPM-Grapevine© supports the analysis of performances and helps to identify the strengths/weaknesses of the tested prototypes. This tool can be used for ex ante assessment to guide the designing of cropping systems. It can also enable to re-adjust the prototypes after field experimentations. A third use for farmers' advisors is to help producers to modify their farming systems to enhance the sustainability of their farms.

Keywords: sustainability multicriteria assessment, DEXiPM, grapevine farming system

Resumé
Mettre en œuvre de nouvelles méthodes d'évaluation de la durabilité de systèmes viticoles est une étape indispensable pour concevoir et développer des systèmes innovants qui répondent aux récents enjeux de l'agriculture durable. DEXiPM-Vigne© en est un exemple. Ce modèle d'évaluation multicritère de la durabilité de systèmes viticoles a été adapté de DEXiPM-Grandes culture (Pelzer et al., 2012).Conçu durant le projet européen PURE 2012-2015 (Solutions de Protection Intégrée des cultures (IPM)), il permet d'évaluer et comparer des systèmes viticoles innovants en réelle rupture avec les systèmes actuels. Ce modèle est composé de 65 variables d'entrée, combinées en 97 attributs agrégés pour l'évaluation des performances économiques, sociales et environnementales. Les pondérations des attributs ainsi que les seuils de leurs classes qualitatives ont été à partir d'une base de connaissances d'experts et d'enquêtes.Un guide d'utilisation aidera les utilisateurs pour un usage adapté à leur contexte d'étude.
Nous avons testé DEXiPM-Vigne© pour analyser les performances de systèmes viticoles innovants, à bas niveau d'intrants phytosanitaires, conçus et expérimentés au sein du réseau français EcoViti qui porte cette démarche d'agronomie systémique. Des analyses *ex ante* et *ex post* ont été conduites pour trier et adapter les stratégies expérimentées. Trois voies principales de réduction des pesticides ont été testées : (i) IPM basé principalement sur l'efficience des méthodes de protection actuelles , (ii) utilisation de produits alternatifs, de l'AB et du biocontrôle, (iii) stratégie sans pesticides utilisant les nouvelles variétés résistantes au mildiou/oïdium. Sept prototypes sont testés actuellement par l'INRA à Angers (Val de Loire), Bordeaux (région atlantique) et Montpellier (region méditerranéenne). Les premières évaluations DEXiPM-Vigne© montrent des performances environnementales élevées pour les stratégies basées sur le biocontrôle et les variétés résistantes. Les stratégies IPM ressortent cependant avec la meilleure durabilité globale, et une durabilité socio-économique plus élevée.
DEXiPM-Vigne© accompagne l'analyse des performances des systèmes viticoles et aide à l'identification des forces et des faiblesses des prototypes testés au champ. Cet outil peut être utilisé dans une approche *ex ante* pour aider à la conception de systèmes viticoles, mais également pour les réajuster après les premières expérimentations au champ. Il est également envisagé d'employer DEXIPM-Vigne comme outil d'accompagnement des viticulteurs dans leur démarche de changements de pratiques en cohérence avec leurs objectifs de production.

Mots-clés : durabilité, évaluation multicritère, DEXiPM, systèmes viticoles.

1 Introduction

The assessment of sustainability and performances of farming systems is a useful key activity for any stakeholder in agriculture (farmers, advisors, policy makers). Multi-performance aims and the multi-functionality of cropping systems require a multidimensional socio-economic and environmental analysis. The main challenge is how to build a comprehensive view of this analysis by manipulating a set of criteria and indicators (Columbus and Bergez, 2013). New tools have been designed to assist multi-criteria evaluations (Carof *et al*., 2013). DEXiPM-Grapevine© is one of these tools that assesses the overall sustainability of grapevine systems. This article presents DEXiPM-Grapevine© and a case study to analyse the performances of innovative grapevine agrosystems, re-designed and tested to achieve high reductions of pesticide inputs (Metral *et al*., 2012).

2 Material and method

DEXiPM is a multicriteria assessment tool. It models the sustainability of cropping systems based on the decomposition of three main pillars (i.e economy, social, and environment) into smaller and less complex criteria (Pelzer, *et al*. 2012). The model is implemented on the open access DEXi software (Bohanec, 2014). DEXi is a decision support system for qualitative assessment of multidimensional problems. DEXi supports the design of hierarchical decision trees and manages the aggregation and the weighting of attributes (branches of the tree). DEXiPM-Grapevine© was adapted from DEXiPM created for arable crops by developers from various disciplines (Sadok *et al*., 2009 and Pelzer *et al.,* 2012) during the European funded project PURE (Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management, www.pure-ipm.eu). DEXiPM has an exhaustive description of environmental sustainability with a wide range of used ressource criteria and biodiversity criteria. The main structure of the initial model was preserved, while specific adaptations were proposed for socio-economic assessments, based on expert knowledge and agronomic surveys on grapevine systems.

In this first version, DEXiPM-Grapevine© is built with 64 basic attributes gathered in 97 aggregated attributes (See Fig. 1). The basic attributes must be filled by the user. They describe the regional context of assessment (farming system strategy, pedoclimatic context), and the technical indicators of the assessed grapevine cropping system. DEXiPM is suitable for either *ex ante* approach, based on a theoretical prototype of the cropping system (Sadok *et al.*, 2009) or *ex post* approach with experimental results of tested cropping systems. In an ex ante use, no calculation is needed. In an ex post use, indicators such as real Treatment Frequency Index (TFI measures pesticides pressure in a cropping system) are calculated and used as attribute.

The DEXi approach is a decision model based on organization into a hierarchy of qualitative multi-attribute. Qualitative classes describe each attribute (low to high). Descendant attributes are aggregated through utility functions and weightings, which results in the ascendant attribute. For instance, overall sustainability (ascendant attribute) is the result of the aggregation of economic, social and environmental sustainability (the three descendant attributes) with a weight of 33% each. The utility function combines the different classes of descendant attributes with a decision rule to build the qualitative scale of the upper attribute (e. g. very low * very low * high = low) (See Fig.1). A trade-off is necessary between an easy-to-use model and a more complex one, with more difficulties for parameterization. DEXiPM-Grapevine© was validated by European experts from PURE project. DEXiPM-Grapevine© is then available for assessment projects of overall sustainability of grapevine cropping systems.

3 Results and discussion

Sustainability assessments produced by DEXiPM-Grapvine© are one of many other indicators that can be used to evaluate a grapevine system. The first DEXiPM-Grapevine© tests were conducted on experimentations of innovative grapevine systems, re-designed to significantly reduce the use of pesticides in the French program EcoViti (Metral *et al.,* 2012).

To show the strenght and weakness of the tool, we propose to analyse three strategies tested in EcoViti network (i) Integrated Pest Management strategy is based on decision support systems in order to reduce pesticide applications and enhance spraying quality in vineyard, (ii) alternative products, organic and biocontrol approach, (iii) pesticide-free cropping systems based on new grapevine mildew resistant varieties. Seven prototypes are tested on INRA experimental farms in Angers (Loire Valley (center of France), Bordeaux (atlantic region), and Montpellier (mediterranean region). IPM sustainability appears better and more balanced compared to the current system on the site of Montpellier (See Fig. 2a and 2b). DEXiPM-Grapevine© shows that the current system is clearly unbalanced: it is optimized on socio-economic aspect, but shows strong gaps on the environmental side. The first result is that DEXiPM-Grapevine© is able to discriminate strategies through a comprehensive qualitative analysis of sustainability performance.

If we now compare the same IPM strategy over 3 years of testing (Fig. 2a), the spider diagrams of DEXiPM Grapevine© assessments show a very low inter-annual overall variability. (Overall sustainaibility still at the highest level, despite some variations in the balance between economy, social and environment). Diseases pressures in 2013 and 2014 are however very different which led to a TFI reduction of 60% in 2014 on the IPM Mourvèdre prototype. This difference did not significantly impact DEXiPM-Grapevine© assessments. This result confirms that DEXiPM-Grapevine© is a comprehensive tool for evaluating strategies in a systemic agronomic approach. Accordingly, it does not allow detailed analysis of marginal changes of the technical system (eg efficiency of a technique).

The comparison between the sustainability of the current system on the experimental farm in Montpellier and the InnoBio system illustrates the trade-off between economy and environment. The overall sustainability of the InnoBio system is higher (5/5 vs 3/5) than the current conventional system (systematic spraying) but showed a lower economic sustainability in 2014 (4/5 vs. 5/5). The challenge to achieve at the same time economic AND environmental performance is not just a simple substitution of chemical products by “greener” ones.

We must re-design the agrosystem toward a strong reduction of all kind of plant protection products. This is what shows the evaluation of the strategy (iii) (resistant variety and pesticide-free) (Fig. 2c), with a maximum sustainability on the social pillar and all environmental components. The economic part gets only the score of 4/5 because resistant varieties are not currently recognized in DOP which limits their profitability. These excellent results are also nuanced by the concerns raised by the pesticide-free strategy in terms of secondary disease pressure such as Black Rot. Black Rot is no longer controlled by the

anti-mildews fungicides. Controlling these diseases is a challenge to maintain expected yields. Some specific pesticide treatments need to be introduced in the system and this requires new DEXiPM Grapevine© simulations.
If we now compare two IPM systems without herbicides (Fig. 2d), each with a specific soil management strategy are designed: (a) cover crop on 100% of soil surface (row + inter-row) and (b) cover crop on 50% of the soil surface (one inter-row out of two), with the current systems (cover crop on 50% of the soil surface and herbicides under the row), the DEXiPM-Grapevine© assessment shows no difference in overall sustainability, social and environmental components.
In contrast, the trade-off is different if we decompose the three main pillars of sustainability. IPM strategies have better environmental performances. The 50% cover crop strategy may be better in economic sustainability over a year (to be confirmed due to annual variability). Moreover, DEXiPM-Grapevine© compares more successfully two main strategies (IPM vs current system), but the differences are less significant and compelling between the two IPM variants. DEXiPM-Grapevine© seems all the more interesting that the choice of re-designed grapevine systems are strong and out. DEXiPM-Grapevine© gives an objective and global view of the socio-economic and environmental sustainability.

4 Conclusion

DEXiPM-Grapevine© is an innovative tool recently developed on grapevine crop to assess in a qualitative and comprehensive way the economic, social and environmental sustainability of grapevine cropping systems in Europe. DEXiPM-Grapevine© runs on free software DEXi and is free to download on the website of the European project PURE (http://www.pure-ipm.eu) from May 2015. Therefore the user is responsible for the information and results that he produces and broadcasts with this tool. A methodology guide is also provided by the designers to help users to fill the model attributes and to adapt class thresholds to the context where DEXiPM-Grapevine© is used. In fact the question of managing comparisons between different contexts is asked. This seems risky with DEXiPM-Grapevine© concerning economic and social aspects, which may be very dependant on different contexts such as the sale price (Vasileiadis *et al*., 2013), but with less doubt on the environmental component. This remains to be tested.
DEXiPM-Grapevine© provides accurate and robust synthetic analysis for theoretical strategy (ex ante) or tested strategy (ex post) of grapevine systems. This is not a tool to analyse or test the efficiency of an individual agricultural technique but it is well adapted to assess the impact of a new technique (such as substitution of herbicide use by tilling) on overall system performances. An important quality of DEXIPM Grapevine© is its ease and speed of implementation compared to other more quantitative approaches such as Life Cycle Analysis. DEXI allows an easy understanding of the final result thanks to an open tree view of the successive attributes. DEXiPM-Grapevine© provides sustainability indicators for grapevine systems which are expected and appreciated by many agricultural stakeholders.

5 Acknowledgments

This study was supported by EU through the PURE project 2012-2015 (FP7-265865 - KBBE.2010.1.2-05), and ONEMA with the DEPHY EXPE Ecophyto program.

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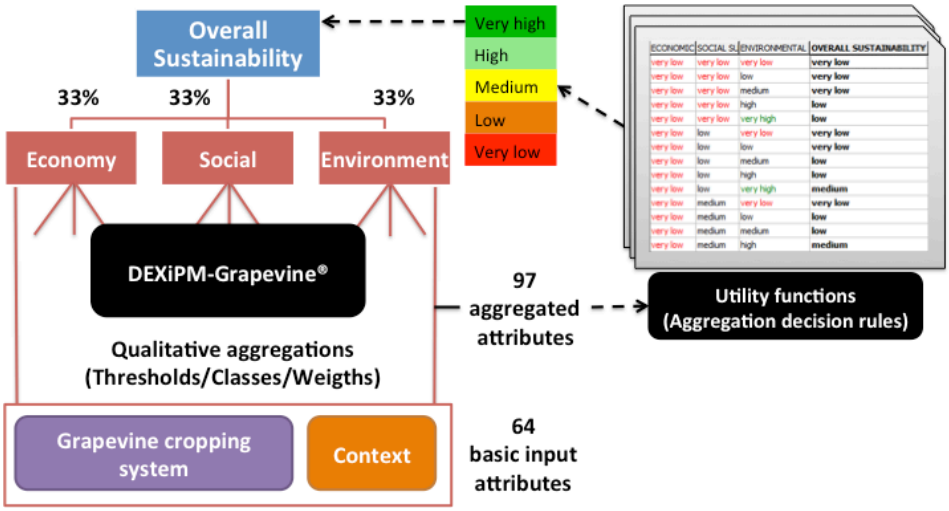

Fig. 1: DEXiPM-Grapevine® general tree-model for sustainability assessment (adapted from Bohanec et al, 2008)

Fig. 1: Modèle général d'arborescence de DEXiPM-Vigne® pour l'évaluation de la durabilité (adapté de Bohanec *et al*, 2008)

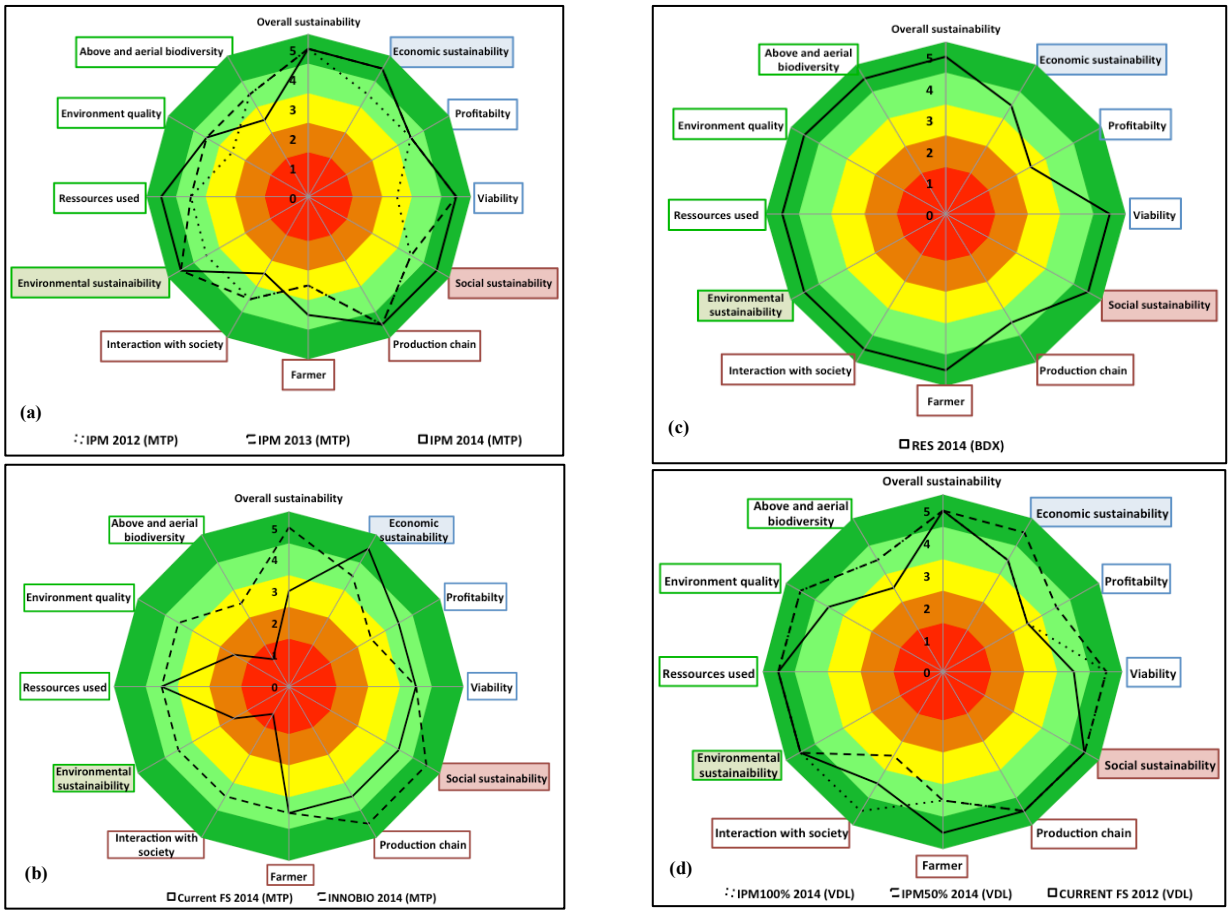

*Fig. 2: Diagrammes of DEXiPM-Grapevine© result from the sustainability assessment of different innovative cropping systems, re-designed in a low pesticide use goal. **(a)** IPM grapevine cropping systems tested in Montpellier (MTP) for three years (2012, 2013, 2014) (Domaine du Chapitre). **(b)** Current grapevine cropping system and InnoBio system (based on organic farming and biocontrol solutions) on the Montpellier (MTP) experimental farm (2014) (Domaine du Chapitre). **(c)** Innovative grapevine croppping system based on mildews resistant varieties and pesticide-free strategy tested in Bordeaux (BDX) (2014) (Domaine de la Grande Ferrade). **(d)** Comparison of two IPM strategies with 50% and 100% of permanent cover crop tested in Loire Valley (VDL) and the current farming system on the farm (Current FS).*

Fig. 2: Résultats DEXiPM-Grapevine© issus de l'évaluation de la durabilité de différents systèmes de culture innovants re-conçus pour réduire l'utilisation des pesticides. **(a)** Systèmes viticoles IPM (protection intégrée) testés trois ans à Montpellier (2012, 2013, 2014) (Domaine du Chapitre). **(b)** Système actuel et InnoBio (basé sur l'Agri Bio et le biocontrôle des bioagresseurs) testé à Montpellier (2014) (Domaine du Chapitre). **(c)** Système viticole innovant utilisant des varieties résistantes Mildiou/Oïdium et une stratégie sans pesticides testé à Bordeaux (2014) (Domaine de la Grande Ferrade). **(d)** Comparaison de deux stratégies IPM (protection intégrée) avec respectivement 50% et 100% d'enherbement permanent et du système de culture actuel testés en Val de Loire (VDL) (Current FS).