AGRINNOV: AN INNOVATIVE PARTICIPATIVE APPROACH TO IMPLEMENT OPERATIONAL INDICATORS AND A SET OF REFERENCES FOR SOIL BIOLOGICAL STATUS IN VINEYARDS

AGRINNOV : UNE APPROCHE PARTICIPATIVE INNOVANTE POUR LA MISE EN PLACE D'INDICATEURS OPÉRATIONNELS ET DE RÉFÉRENTIELS DE L'ÉTAT BIOLOGIQUE DES SOLS VITICOLES

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Abstract
Soil, through its biological component, plays a key role in agroecosystem functioning. In a context of cropping system evolution, new tools have to be determined in order to assess the impact of these systems on soil organisms. AgrInnov is a French participative project which associates researchers and farmers. It aims at developing operational tools to characterize soil biodiversity and at building up a set of references to understand and interpret this biodiversity. The method consisted in selecting operational bio-indicators among the existing ones which could be used and validated scientifically. The chosen bio-indicators target three main groups of soil organisms: earthworms, nematodes and the microbial community. These living organisms ensure biological functions and services provided by the soil and are sensitive to some farming practices. At the same time, indicators for agronomical assessment have been implemented: soil physico-chemical properties, soil structure and organic matter decomposition. The project relies on a network of 113 vineyard plots which integrates a large diversity of pedoclimatic and practices backgrounds at the French territory scale. In 2013-2014, winegrowers themselves proceeded to soil sampling for laboratory measurement and data collection from fields, after having received a training and supplied with a handbook. Results obtained allowed to establish a range of variation for each of the bio-indicators in different pedoclimatic contexts. Two synthetic indicators were defined to show the impact of cropping systems and associated practices on biological soil quality and on biological and ecological functioning of the soil. AgrInnov allowed validating a set of references for soil biological status which could be used by winegrowers to assess the sustainability of their practices.

Keywords : *bioindicator, soil, microorganisms, nematode, earthworm*

Résumé
Le sol, à travers sa composante biologique, joue un rôle essentiel dans le fonctionnement des agrosystèmes. Dans un contexte de développement durable, il apparaît indispensable de se doter d'outils permettant d'appréhender les impacts des systèmes de culture sur les organismes du sol. AgrInnov est un projet participatif français associant chercheurs et agriculteurs ; il vise à développer des outils opérationnels de caractérisation de la biodiversité dans les sols ainsi qu'à la construction de référentiels d'interprétation de cette biodiversité. La méthode a consisté à sélectionner les bio-indicateurs opérationnels utilisables parmi ceux existants et validés scientifiquement. Les bio-indicateurs retenus ciblent trois grands groupes d'organismes du sol : les vers de terre, les nématodes et les communautés microbiennes. En parallèle, des indicateurs d'évaluation agronomique sont mis en place : analyses physicochimiques du sol, observation de la structure du sol, évaluation de l'activité de décomposition de la matière organique. Le projet s'appuie sur un réseau de 117 parcelles viticoles qui intègre une grande diversité de situations pédoclimatiques et culturales à l'échelle du territoire français. En 2013-2014, les viticulteurs ont réalisé eux-mêmes l'échantillonnage de sol pour les mesures en laboratoire et l'acquisition des données terrain, après avoir reçu une formation et un guide pratique élaborés à cet effet. Les résultats obtenus ont permis d'établir une gamme de variation pour chacun des bio-indicateurs dans différents contextes pédoclimatiques. Deux indicateurs de synthèse ont également été construits afin de rendre compte de l'impact des systèmes de culture et des pratiques agricoles sur les services rendus par la biodiversité du sol : patrimoine biologique - insurance écologique et fertilité biologique. AgrInnov a permis de valider un set opérationnel d'indicateurs de l'état biologique du sol et son référentiel d'interprétation utilisables par les viticulteurs.

Mots-clés : bioindicateur, sol, micro-organismes, nématodes, vers de terre

1. Introduction

Soil is a non-renewable resource which plays a key role in agroecosystems functioning, especially through its biological component. Living organisms ensure biological functions and services provided by the soil and are sensitive to some farming practices. Soil microorganisms are involved in a great diversity of functions such as organic matter decomposition, humus formation, soil aggregation, nutrient recycling and retention… Soil nematodes are relevant bioindicators of soil quality thanks to their role in mineralization processes; moreover they are ubiquitous and present in all pedo-climatic situations (Salomé et al., 2014; Coll et al., 2011). Earthworms play a key-role in the degradation and mixing of organic matter, and in the soil structuration (Blouin et al., 2013). Today, there is a crucial need in agriculture to reduce the use of external inputs (e.g. pesticides, mineral fertilizers…) while preserving soil fertility and quality by the use of innovative agricultural systems. In this context of cropping system evolution, new tools have to be developed to assess the impact of these systems on soil quality. Up to now, soil quality is generally evaluated by the interpretation of well-known physical or chemical indicators. However, recent breakthroughs in research allow a more complete evaluation of soil quality by using biological indicators (Dequiedt *et al*., 2011). Research must provide and transfer knowledge developments in soil biology and newly developed measurement tools, to help growers to better protect their soil patrimony, to assess and improve the sustainability of their cropping system by finalizing an operational soil diagnosis.

AgrInnov is a French participative project which associates researchers and farmers. It aims at developing operational tools to characterize soils biodiversity and building up a set of references to understand and interpret this biodiversity. To do so, AgrInnov has the following objectives: i. to select and validate operational soil biological and agronomical indicators; ii. to transfer the selected indicators and the associated knowledge to soil users (training), iii. to implement a set of references for soil biological status in vineyards. AgrInnov project will end up in June 2015. In this article, the method implemented and the type of results (which may be transferred to soil users at the end of the project) will be presented.

2. Material and methods

The method consisted in selecting operational bio-indicators and agronomic indicators which could be used among the existing ones and validated scientifically. Selection was made according to various criteria: scientific robustness (existence of reference tables for interpretation), applicability to a network of farming systems, interest of farmers in the indicator and easiness of use, cost, and existence of laboratories able to analyze these indicators during the project lifetime and beyond.

The chosen bio-indicators target three main groups of soil organisms: microbial community, nematodes and earthworms. These living organisms ensure biological functions and services provided by the soil and are sensitive to some farming practices. At the same time, indicators for agronomical assessment have been implemented to enrich soil diagnosis: soil physico-chemical analyses, soil structure and organic matter decomposition.

The project relies on a network of 117 vineyard plots which integrates a large diversity of pedoclimatic and practices backgrounds at the French territory scale. Vineyards of Loire Valley, Bordeaux, South-West, Provence, Burgundy, Beaujolais, Jura and Champagne were represented. Winegrowers were chosen on a voluntary basis, the initial objective was to reach a sample size of one hundred vine plots. In 2013-2014, winegrowers proceeded to soil sampling for laboratory measurements and data collection in fields by themselves, after having been trained and given a handbook. In parallel a survey was built and submitted to farmers in order to register their vine management systems and practices on the sampled plots.

Winegrowers training and soil sampling

Each winegrower received a one-day training divided into i. theoretical part on soil biodiversity and ecology, ii. applied part with field application of sampling protocols. Training has been specially designed and developed by the project team which included agronomists and soil biologists. A total of ten training sessions were organized.

The analyses of physico-chemical, microbiological and nematological indicators were conducted on the basis of composite soil samples from the topsoil horizon (0-20 cm) collected by the winegrowers. Within each selected plot, a homogeneous and representative sampling area was identified by the farmer. The width of the area consisted of three successive inter-rows with same soil management practices while its length was set at around 20 m. Fifteen soil cores were collected within the defined area, only in inter-rows maintained identically, and homogenized to form two composite soil samples: one for physico-chemical and microbiological analyses, another one for nematological analysis. Soil samples were sent immediately after collection to different specialized labs.

Agronomic indicators and earthworm collection were implemented within the same sampling area. Most of the observations and sampling were carried out between November 2013 and March 2014. Sampling protocols for each indicator were described step by step in a handbook – written for this purpose by the project members – which was given to farmers the day of their training, together with the necessary equipment.

Agronomic indicators

Soil samples were first prepared and placed in the conservatory at the French National Institute for Agricultural Research (INRA) service unit InfoSol in Orléans. Physico-chemical analyses were performed in the Laboratory for Soil Analysis in Arras (LAS) which is the INRA central laboratory for soil analyses. Variables analyzed included soil texture, organic carbon and total nitrogen contents, total limestone content, pH(H_2O), available phosphorus, CEC, exchangeable cations and trace elements.

A visual assessment of soil structure was realized by the winegrowers using the "spade test" method derived from "profil cultural" method (Manichon et Gautronneau, 1987). Firstly, soil surface was observed in order to identify any trace of crusting or erosion and of biological activity. Secondly, a soil block – 20cm x 20cm x 25cm deep – was extracted with a spade. Internal structural state of clods (no visible porosity, no visible porosity with cracks, or visible porosity) and type of structural state of the whole block (continuous, porous) were characterized on the spadeful of soil. These observations allowed establishing the level of soil compaction. Six repetitions of spade test were performed for each plot.

Organic Matter degradation was estimated by using the litterbag method. Mesh bags, 15 x 20 cm, filled with standard organic matter (cereal straw) were buried into soil at 10 cm depth. Mesh size of 1 mm was determined to consider microorganisms and mesofauna biological activity. Litterbags, provided to wine growers by the Laboratory of Plant Ecophysiology and Agroecology (LEVA, Angers), were left four months in the topsoil horizon, from March to June. Then, they were collected and sent back to LEVA for estimating organic matter degradation by mass loss measurement. Three litterbags were deployed per plot.

Biological indicators

Microbiological characterization was carried out by the GenoSol Platform which is part of the Agroecology research unit at INRA Dijon, using a molecular characterization method of the microbial metagenome. Quantification and sequencing of microbial DNA resulted in several elementary indicators related to microbial abundance and diversity: molecular microbial biomass, fungal/bacterial ratio, richness in bacterial and fungal species.

Nematologic analyses were conducted by a specialized laboratory named Elisol Environnement and located in Montpellier. Nematodes were extracted from soil samples using the elutriation technique (separation of nematodes from other soil particles by density in a water stream), followed by an active passage through a cotton wool filter. Nematodes were subsequently counted under a binocular magnifier. After their fixation, they were identified (families and/or genera) using optical microscope based on the norm. This method helped building a table of the abundances of nematode taxa serving as a basis for diagnosis. On the basis of the composition and abundance of soil Nematofauna, several indices were calculated: Structure Index (SI) which reflects the stability of habitat, Enrichment Index (EI) which gives an indication of the dynamics of nutrients. Each soil was consequently characterized by the abundances of different functional groups of nematodes and by nematofaunistic indices.

Earthworms were collected by hand-sorting by winegrowers themselves, while they were assessing soil structure, on a volume of soil of 20cm x 20cm x 25cm deep. Earthworms were counted, rinsed, identified (optional) depending on the stage of sexual maturity (adult or juvenile) and according to 4 ecological groups (epigeic, "redhead" anecic, "blackhead" anecic, endogeic). Then they were stored in pillbox filled with ethanol during their transportation to the University of Rennes 1 where they were identified up to the specie level and weighed. It resulted in several elementary indicators related to earthworm's abundance and diversity: total biomass, total abundance, abundance by ecological group, abundance by species, species richness.

All data were stored in a unique database hosted by the French Observatory for Living Soils (OFSV).

3. Results and discussion

Training efficiency

After having received a one-day training, 94% of the viticulturists have realized soil sampling allowing the achievement of soil physico-chemical, microbiological and nematological analyses. 88% of winegrowers performed spade test with earthworm hand-sorting. 70% returned the litterbags to the laboratory. The training process which was experimented showed a good efficiency.

Construction of synthetic indicators and individual feedbacks to winegrowers

Results obtained allowed to establish a range of variation for each indicator in different pedoclimatic contexts. Data were first analyzed plot-by-plot in order to return individual results to winegrowers. Feedback conferences were organized in January 2015 in the vineyards under study. For each elementary indicator, plots were positioned in regard to the set of references acquired during the project. AgrInnov set of references was supplemented by references achieved on 36 vine plots within a French soil quality monitoring program called RMQS (Soil Quality Measurement Network) for physico-chemical and microbiological data, and by references from ELIPTO© database for nematofaunistic indices. An example of a set of individual data obtained in matter of earthworm abundance within the Gascony Vineyard (South-West of France) is given in figure 1. It illustrates the great variability of one of the component of soil biodiversity within a unique geographical area.

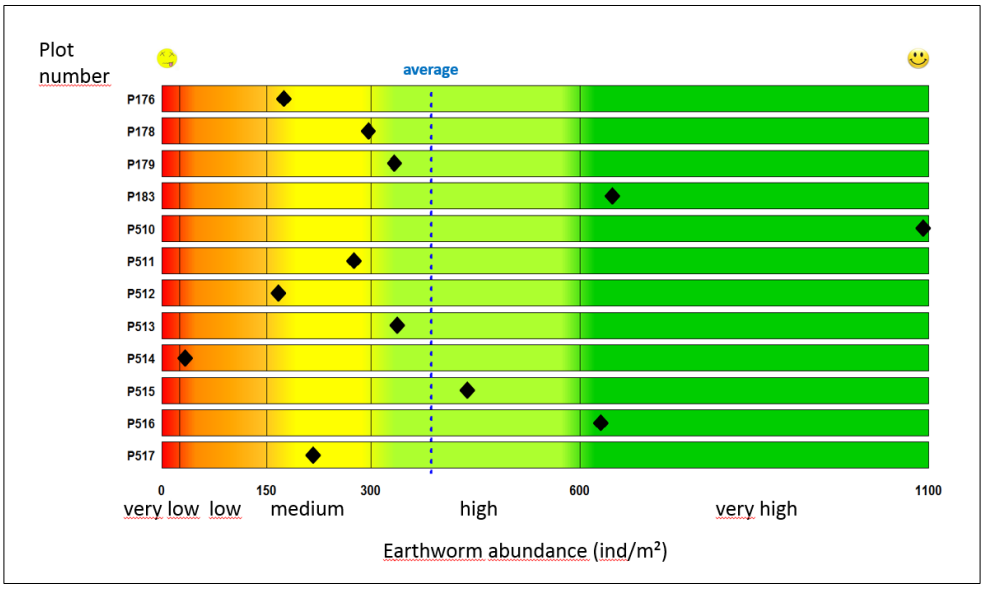

Figure 1. *Total earthworm abundance (individuals/m²): Positioning of the recorded values of the 12 plots of the Gascony vineyard compared to all values within the program AgrInnov (110 plots).*

Figure 1. Abondance lombricienne totale (individus/m²) : Positionnement des valeurs enregistrées sur les 12 parcelles du vignoble Côtes de Gascogne par rapport à l'ensemble des valeurs obtenues dans le cadre du programme AgrInnov (110 parcelles).

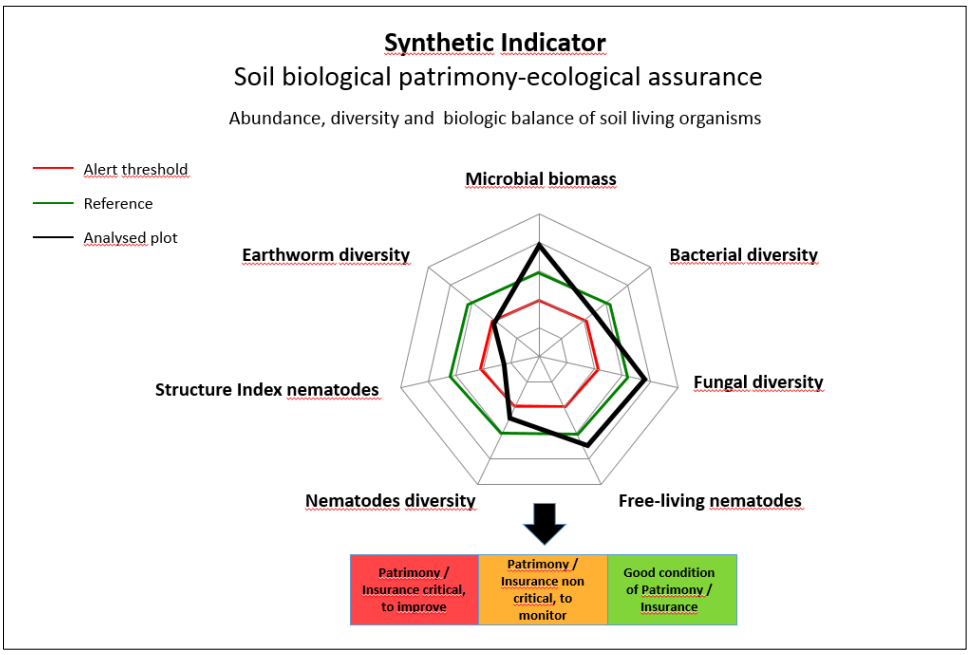

Figure 2. *Illustration of the synthetic indicator "soil biological patrimony – ecological insurance" result obtained for one plot of the AgrInnov network.*

Figure 2. Illustration des résultats des bioindicateurs agrégés sous forme d'un indicateur synthétique « patrimoine biologique du sol – assurance écologiqe » pour une des parcelles du réseau AgrInnov.

To complete the soil diagnosis destined to farmers, two synthetic indicators were defined – "biological patrimony - ecological insurance" and "biological fertility" – to report the impact of the cropping system and of the associated practices of each plot on biological soil quality and on biological and ecological functioning of the soil. The concept of ecological insurance reflects the fact that a high diversity of species in an ecosystem leads to better stability of communities following a disturbance which, consequently, maintains the essential functions of the ecosystem. "Biological patrimony and ecological insurance" synthetic indicator was built by aggregating seven elementary indicators related to soil organisms' diversity and abundance: microbial biomass, bacterial diversity, fungal diversity, earthworms' diversity, abundance of free-living nematodes, nematode diversity and nematofauna Structure Index (SI) – which reflects the stability of habitat and depends on the relative abundance of several families (bacterivores, fungivores, omnivores and predators). "Biological fertility" synthetic indicator was built by aggregating biological and agronomic elementary indicators: soil structural state (spade test), organic matter decomposition rate within litterbag, bacterial diversity, fungal diversity, fungal/bacterial ratio, abundance of free-living nematodes, Enrichment Index (EI) based on the composition and abundance of soil nematofauna to give an indication of the dynamics of nutrients, anecic earthworm abundance and endogeic earthworms' abundance. An illustration of the resulting synthetic indicator for one of the plot from the network is given in figure 2. For each elementary indicator composing the synthetic indicator, alert thresholds were defined below which soil functions may no longer be insured. Knowledge transfer was performed in order to help winegrowers to understand a set of information they are not used to getting.

4. Conclusion and prospect

Results obtained allowed establishing a range of variation for each of the bio-indicators in different pedoclimatic contexts (not shown in this paper). This is an important step because perennial cropping systems are among the least informed regarding soil biodiversity. Two synthetic indicators were defined to report the impact of the cropping system of each plot on biological soil quality and on biological and ecological functioning of the soil: "biological patrimony-ecological insurance" and "biological fertility". AgrInnov succeeded in validating a set of operational indicators with associated references for soil biological status which could be used by winegrowers to access the environmental sustainability of their practices.

AgrInnov project will end up in June 2015. The data analysis at a national scale (which is still under process) should give more information on the impact of vine management systems and practices on soil biology and services it provides. However several developments of the project have already been identified: training for farmers and agronomists, network expansion by including additional farmers but also other soil users and developing a new sector of analyses and agronomic consulting.

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